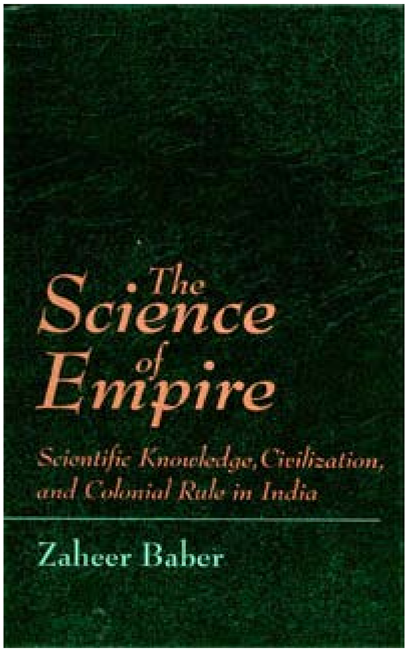

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The Science of Empire

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The Science of Empire

Scientific Knowledge, Civilization, and Colonial Rule in India

Zaheer Baber

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For the victims of
communal violence in India

1
Introduction

Too many of the younger Germans simply make use of the phrase historical materialism only in order to get their relatively scanty historical knowledge constructed into a neat system as quickly as possible. The materialist conception of history has a lot of them nowadays, to whom it serves as an excuse for not studying history. Our construction of history is above all a guide to study, not a lever for construction after the manner of the Hegelian.
Frederick Engels 1

Unless one assumes some trans-historical theory of the nature of history, or that man in society is a non-historical entity, no social science can be assumed to transcend history. All sociology worthy of the name is "historical sociology".
C. Wright Mills2

In my understanding of history and sociology, there can be no relation between them because, in terms of their fundamental preoccupations, history and sociology are and always have been the same thing. Both seek to

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understand the puzzle of human agency and both seek to do so in terms of the process of social structuring. Both are impelled to conceive of that process chronologically; at the end of the debate the diachrony-synchrony distinction is absurd. Sociology must be concerned with eventuation, because that is how structuring happens. History must be

theoretical, because that is how structuring is apprehended. Historical sociology is thus not some special kind of sociology; rather, it is the essence of sociology.
Philip Abrams 3

What distinguishes social sciences from history? I think we have to reply as Durkheim did nothingnothing, that is, which is conceptually coherent or intellectually defensible.
Anthony Giddens4

Over two decades ago, Benjamin Nelson observed that the micro-sociological perspectives that dominated the sociology of science had "largely spent themselves," and he expressed the hope that the neglected comparative historical and civilizational perspective pioneered by Joseph Needham would once again be utilized to investigate issues like the "struggles over the new science in nineteenth-century India".5Nelson's mixture of hope and prediction of the decline of the microsociological perspective proved to be premature. Barring a few outstanding exceptions, the "new" sociology of science, continues to be dominated by repeated attempts to demonstrate the fact that scientific facts are socially constructed.6While analyses governed by such a perspective have no doubt contributed substantially to our understanding of the scientific enterprise, they have also at times engendered extreme ontological relativism bordering on solipsism.7

The major contribution of the constructivist perspective has been to question the normative view of science and the scientific enterprise that allowed little if any role for scientists as active agents involved in the production of knowledge. The sociological studies of scientific practice that gathered momentum in the mid-seventies and have continued to profilerate ever since depicted scientists as actively engaged in the process of constructing scientific facts. Detailed ethnographic studies of scientists at work produced a picture that was more complex than some normative accounts of science had allowed.

A number of social factors were implicated in the production of scientific facts, and practitioners of the "new" sociology of science focused on the complex negotiations and power struggles that constituted essential components of the scientific enterprise. Despite their many differences, proponents and followers of various theoretical perspectives within the sociology of science agreed on some version of the "constructivist perspective"the theory that scientific facts are socially constructed, and social factors influence the very content of scientific knowledge. Drawing on the work of Thomas Kuhn, the new practitioners of the sociology of scientific knowledge characterized their work as inaugurating a "post-Mertonian" phase in the sociology of science. However, as Sal Restivo has argued, it was a questionable interpretation and appropriation of Kuhn's work, and nobody was more surprised than Kuhn himself at the relativist "Kuhnian revolution" that the mainly British sociologists sought to herald. 8More recently the continuing preoccupation of some sociologists with purely epistemological issues has led Kuhn to count himself "among those who have found the claims of the strong program absurd: an example of deconstruction gone mad."9At the same time, as Thomas Gieryn has convincingly argued, Robert Merton, one of the main targets of the "new" sociologists of scientific knowledge, was not as innocent of the social constructivist perspective as the more enthusiastic proponents of the post-Mertonian era have claimed. As Gieryn puts it, "many of the empirical findings of the relativist/constructivist programme, when stripped of polemical manifestos and trendy neologisms, could be expected from Merton's theories, and some are anticipated by his occasional steps into empirical research."10While it would be inaccurate to argue that Merton's work exhausted the range of perspectives and topics in the sociology of science, a careful rereading of his writings would reveal that the much vaunted novelty of the post-Mertonian turn was not quite warranted. Perhaps exemplifying the social constructivist program in action, the "new" sociologists of science had constructed and interpreted key Kuhnian and Mertonian texts in line with their own intellectual agendas.

While research resulting from the early phase of the constructivist program played a significant role in demystifying and deconstructing the idealized image of scientific practice, the recent work of some practitioners of the sociology of scientific knowledge comes close to exemplifying what Kuhn termed "deconstruction gone mad."11Quite clearly, any attempt to subject scientific knowledge to sociological scrutiny is likely to involve an epistemologically relativist stance toward scientific facts. Otherwise one could simply adopt the normative, idealized image of what the practice of science is supposed to be. However in recent years, the sociological critique of the "essentialist"12or "standard"13view of science, has taken a rather curious turn. If the original impetus for revising the "essentialist" view of science was to argue that scientists were engaged in much more than passively describing and

recording the natural world, then research demonstrating that factors other than "nature" were implicated in the construction of scientific facts was indeed helpful in opening up the "black box" of science. In keeping with the spirit of establishing the fact that scientific knowledge was influenced by social factors and therefore amenable to sociological analysis, the early post-Mertonian, relativist sociologists of science downplayed the role of the natural world in the construction of scientific facts. However most sociologists, even while engaged in research driven by "epistemic relativism" cautioned against the adoption of a position of "ontological relativism." 14While insisting that scientific facts are socially constructed, few wanted to argue that the natural world had no role in this process. As Barnes put it more than two decades ago: "Occasionally, existing work leaves the feeling that reality has nothing to do with what is socially constructed or negotiated to count as natural knowledge, but we may safely assume that this impression is an accidental by-product of over-enthusiastic sociological analysis, and that sociologists as a whole would acknowledge that the world in some way constrains what is believed to be."15In a similar vein, Michael Mulkay, while arguing that there is "nothing in the physical world which uniquely determines the conclusions of the scientific community," felt it necessary to add that "it is of course self-evident that the external world exerts constraints on the conclusions of science."16

There have always been critics of the position that allowed the natural world some role, however minimal, in the constitution of scientific facts. One of the most strident of these critics continues to be Steve Woolgar who has consistently taken most sociologists of science to task for not being relativist enough. Thus proponents of the "strong program" are criticized by Woolgar for being "uncertain about taking issue with a further key assumption, that the world exists independently of, and prior to, knowledge produced about it."17Much of the existing work in the sociology of science is criticized by him for being "epistemologically relativist and ontologically realist." As Woolgar sees it, this state of affairs seems rather "curious given that a major thrust of post-modern critiques of science is to suggest the essential equivalence of ontology and epistemology: How we know *is* what exists."18Woolgar's aim is to introduce a radical ontological relativism that questions the idea that the natural world has any role in the formulation of scientific facts or in adjudicating the choice between rival theories. His main objective is to invert the "presumed relationship between representation and object" and to argue and defend the proposition that "the representation gives rise to the object."19For Woolgar, the scientific laboratory and the culture of scientific research comprise a "moral order of entities" or "technologies of representation," where "the objects of the natural world are constituted in virtue of representation."20Dispensing with the note of caution injected by the sociologists who inaugurated the constructivist tradition in the sociology of science, Woolgar and his colleagues have now embarked on a "reflexive" project that aims to deconstruct not just the concept

of science and technology but also what are perceived to be the scientific pretensions of the sociology of science.

While the issue of reflexivity is an important one for sociology, Woolgar and his colleagues' understanding of the term and its significance for sociology are quite different from the way it was conceptualized by Gouldner, Bourdieu, or Giddens. Woolgar's argument is that while sociologists of science have successfully demonstrated the socially constructed nature of scientific facts, they have failed to apply the same tools of "deconstruction" to their own accounts of scientific activity. While such a critique of the existing work in the sociology of science is fair to a degree, it is not clear whether such a mode of analysis has contributed much to the understanding of the interface between science, technology, and society. Despite repeated attempts to allay the fears of those who fear the worst, the reflexive project seems to be well on its way toward deconstructing science and technology out of existence. Indeed recent work informed by the reflexive perspective or the general "linguistic" turn has precious little to say about science and technology and is overburdened by discussions of the ideas of fellow sociologists of sciencereal, constructed and sometimes completely imagined. 21

The precise role the natural world plays or does not play in the construction of scientific facts will continue to be debated vigorously, and it is quite unlikely that a consensus on the issue will ever emerge.22While the key assumption of the constructivist perspective, that scientific facts are theory-laden and acquire stability as a consequence of the activity of scientists, is a truism for most contemporary sociologists of science, and while most practicing scientists will hardly be surprised by this approach, extending this perspective to argue for ontological relativism as Woolgar and some

proponents of the "strong program" do is inherently problematic. The program of ontological relativism, which denies any role whatsoever to the natural world, has been questioned by a number of sociologists. Most recently, Kyung-Man Kim has argued that such an "ontologically nihilistic sociology of science can never provide us with a plausible causal scenario as to the belief change process of scientists and hence cannot cope with the problem of explaining theory change in science."23Kim has convincingly questioned "strong programmer" David Bloor's theory that "any negative experimental results can be reinterpreted at will so that they fit the social conventions of one's preferred theory" and has argued for a theory that emphasizes a "process of constant modification through interaction with the natural world."24

In a similar vein, Roy Bhaskar has distinguished between the "intransitive objects of scientific inquiry" that exist and act independently of our knowledge of them, and the "transitive dimension," or epistemology, that enables us to make sense of the natural world. Such a distinction does not mean that Bhaskar is the naive realist as caricatured by Steve Woolgar and others.25Bhaskar's distinction between the two dimensions of scientific inquiry enables

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him to conceptualize science "as a social process, irreducible to an individual acquisition, whose aim is the production of the knowledge of the mechanisms of the production of phenomena in nature, the intransitive objects of inquiry." 26Bhaskar's "critical realist" perspective retains the distinction between epistemology and ontology that Woolgar, by arguing that "how we know *is* what exists" tries to erase. Unlike Woolgar, Bhaskar's perspective offers a non-anthropocentric account of the natural world and its role in the development of scientific knowledge. And contrary to the caricatures of this position, constructed mainly by the radical constructivists, Bhaskar's critical realism construes the natural world as "a presupposition of our causal investigations of nature, but our knowledge of it is socially and laboriously constructedwith the cognitive resources at our disposal, on the basis of the effects of those investigations."27Bhaskar's critical realism offers a perspective that incorporates the constructivist position without lapsing into the epistemological and ontological idealism advocated by Woolgar and other reflexivists.

A perspective quite similar to Bhaskar's has been offered by the sociologist of science Steven Yearley. Yearley has argued for "moderate constructionism," a theoretical perspective, which, together with elements of Bhaskar's "critical realism," informs the present study. Yearley does not discount many of the insights offered by the constructivist perspective, but, like Bhaskar, he is not willing to accept ontological idealism. As he puts it, "science and technology are not *mere* social constructions; but constructions they are all the same."28What is useful for the purposes of this study is Yearley's attempt to combine what he terms "a social construction view and a political economy view." While proponents of the first perspective reject the idea that scientific knowledge and technological developments unfold in a pre-set, asocial manner, they usually do not move beyond the microsociological level of analysis. The political economy perspective, on the other hand, draws attention to the larger institutional structures to examine how the development of scientific and technical knowledge is influenced by political and economic priorities. Yearley's attempt to combine both these perspectives offers a powerful theoretical tool for questioning the view that science and technology are asocial institutions whose development is driven by the unfolding of an internal logic. Together with the recent writings of Chandra Mukerji,29Stephan Fuchs,30and Donald MacKenzie,31among others, Yearley's perspective contributes to "bringing sociology back in" to a field that has been dominated by discussions of epistemological and philosophical issues leading to endless, labored demonstrations of some version of the constructivist thesis.

One of the unintended consequences of the proliferation of various "relativist" and "constructivist" programs has been a total neglect of what Thomas Gieryn has termed "the constitutive historical question of the sociology of science: what explains the origins of modern science in the seventeenth century, and its ascendance in four centuries to a position of cognitive monopoly over

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certain spheres of decisions?" 32Such historical questions which informed the early work of Robert Merton,33Joseph Needham, and Edgar Zilsel,34among others, are rarely posed by contemporary sociologists of science.35While historians of science have incorporated many sociological concepts and analytical tools in their analyses, sociologists have been much more reluctant to reciprocate.

However in view of the fact that now, more than ever, modern science is being perceived as a "social problem,"[36] and seems to be directly implicated in the emerging environmental crisis, such historical questions are extremely relevant. Philip Abrams' challenge"try asking serious questions about the contemporary world and see if you can do without historical answers"[37] explicitly articulates a view that was always incorporated into the work of classical sociologists and is particularly relevant for understanding the role of modern science and technology in the contemporary world.

This study departs from the currently dominant tendencies within the sociology of science by investigating the complex social processes involved in the introduction and institutionalization of Western science in colonial India. The point of departure lies not in the rejection of the insights of the constructivist perspective, but rather in the attempt to articulate it with an explicitly institutional and historical dimension. The colonial encounter between India and Britain represents an important and fascinating but relatively unexplored chapter in the historical constitution of Western science and technology. India constitutes an interesting area for such a study because, like many other cultures, it has a distinct legacy of indigenous science and technology. In fact, as Joseph Needham has amply demonstrated through his monumental studies, "before the fourteenth century A.D., Europe was almost wholly receiving from Asia than giving, especially in the field of technology."[38] Although Needham is referring mainly to China, his multivolume *Science and Civilization in China*[39] incorporates numerous discussions of particular scientific and technological innovations diffused from India to China through the spread of Buddhism. In view of the proliferation of distinctive indigenous forms of scientific knowledge and technology at various times in India, the introduction of Western science and technology in such a milieu in the late eighteenth and nineteenth century is a neglected topic that deserves further investigation. As demonstrated in this study, the colonial encounter in the sphere of science had significant consequences not just for science in India but also for the development of Western science and technology.

The introduction of Western science and technology in British India was by no means a smooth and uncontested process. In the initial stages of the consolidation of colonial rule, there was no discernable science and technology policy. More often than not, the perception of local conditions and circumstances by colonial administrators led to the utilization of scientific and technological expertise available among the British servants of the East India

Company in India. In fact during the early phases of colonial rule, the Court of Directors of the East India Company, based in London, was not always willing to authorize funds for the scientific projects planned by British administrators in India. For a trading company, the prospect of unnecessary expenditure without any promise of immediate returns, was not a desirable policy. It was only after an initial period of conflict and disagreement between London and Calcutta that the Court of Directors realized the significance of the application of science and technology for the expansion of colonial rule and the augmentation of revenues from India. At the same time, a number of amateur scientists employed by the Company, perceived India to be a vast, unexplored territory that held out the promise of totally new flora and fauna, and the consequent possibility of developing their careers as "scientists." These amateur scientists were actively seeking out patronage for exploration and research, and over a period of time, their scientific interests overlapped with the pecuniary and administrative interests of the East India Company.

By the mid-nineteenth century, colonial India constituted the site for one of the largest, state-sponsored scientific and technological enterprises undertaken anywhere in modern times. During the course of colonial rule, India literally constituted a "social laboratory" where a number of "experiments" in institution building were planned and executed.[40] The experience of developing scientific institutions in British India contributed to a fund of information that was later utilized in Britain. At the same time, specific colonial policies led to the decline and then withdrawal of patronage for indigenous scientific and educational institutions. In the context of rapid structural transformation, initiated in part by colonial policies, the interests of the emergent elites within India were intertwined with the evolving colonial social structure. Under changed social conditions, the elite, urban, and anglicized sections of the Indian population attempted to utilize the existing colonial structures to further consolidate and legitimize their status. These sections of the Indian population were active in demanding the expansion of education in Western science and technology, as it was perceived to be one of the avenues for social mobility in colonial India. This particular configuration of "structure" and "agency" created the conditions for the introduction and institutionalization of Western science and technology in colonial India, a process that constitutes the main focus of this study.

In examining this process, three interconnected issues are explored in detail. First, the manifold ways in which the scientific and technological projects of nineteenth-century British India were intimately intertwined with colonial

imperatives. Western science and technology played active roles, both in the expansion of colonial rule and in the exercise and consolidation of colonial power. As will be demonstrated in this study, scientific and technological projects were frequently perceived by British administrators as visible symbols of colonial power and deployed for the legitimation of colonial rule. A second

theme explored here is the impact of colonial rule on indigenous scientific knowledge and institutions, and some of the social and scientific consequences of this cross-cultural scientific encounter. Such a focus includes a detailed examination and analysis of the varied responses of Indians to the introduction of Western science and technology.

A third and related focus of this study is the investigation of the active role of scientists, both British and Indian, in the transfer and institutionalization of Western science in India, and the creation of new scientific knowledge and institutions in the process. Prior to the emergence of the modern "world-system," one could, despite the limited scientific exchanges across cultural boundaries, identify specific cultural traditions in science and technology. However, the emergence of the modern colonial empires witnessed the development of certain scientific traditions and institutions that transcended national and cultural boundaries. The introduction of Western science and technology in India constituted one such process facilitated partly by the "active involvement of scientists in creating a transnational culture, developing common communication strategies and, at the same, erasing cultural differences." 41Of course, total erasure of differences in scientific traditions may never be possible, or necessarily a good thing, but the attempt at such globalization of scientific and technological institutions can lend itself to synthesis and the creation of new patterns of scientific knowledge.

In a way, colonialism, science, and technology constituted the conditions for the development of each other. This process was nowhere as clearly evident as in the case of the British Empire in India, which constitutes a significant, albeit relatively neglected phase in the development of modern Western science and technology. In recent years, some scholars have examined the relationship among science, technology, and empire in India.42Although these pioneering studies have contributed to a large fund of knowledge and stimulated further research on the practice of science and technology in colonial India, most of them have offered a rather mechanical interpretation and have not paid much attention to the mutually constitutive interplay of structure and agency, colonial power and scientific knowledge, implicated in the process. The general tendency has been to portray Indian society as a passive entity at the receiving end of scientific interventions by an omnipotent colonial state. Other scholars like Susantha Goonatilake and Claude Alvares43have depicted precolonial south Asia as a region of tremendous scientific creativity and originality whose route to further development along a specific cultural trajectory was suddenly disrupted and destroyed by colonial rule. Such arguments tend to substitute empirical evidence and rigorous sociological analysis with a populist third worldism and teleological thinking that is ahistorical and does not stand up to critical scrutiny. The fact that colonial rule led to far-reaching structural transformations and had many negative consequences for India and other societies is obvious. What is required is to go beyond repeatedly stating

the obvious to analyze the complexities of colonial rule and its consequences for the development of science and technology not just in the colonized societies but in Britain, too.

The argument that Western science and technology were nothing more than surrogates for colonialist and imperialist ideology and interests is as limited as George Basalla's simplistic, ahistorical, yet much discussed, three-stage diffusionist model that ascribes a benign, "civilizing" role to colonialism as the main agency for the spread of science and technology from the "core" to the nonscientific "periphery." 44As this study hopes to demonstrate, neither of these perspectives capture the complexities of the process. Science and technology did indeed contribute to colonial expansion and the legitimation of power, but colonial rule itself led to the creation of new forms of knowledge and institutions that were replicated in Britain and elsewhere. The tension between the structures of colonialism and the agency of scientists, first British and later Indian, provided the conditions for structural transformations that had far-reaching consequences for the trajectory of scientific knowledge and institutions as well as the further development of Indian and British society. It is hoped that this study will contribute to an understanding of these issues and to the growing number of studies that have begun examining the multifaceted, complex, and, at times, contradictory relationship among science, technology, and

colonialism.45

Ramachandra Guha has recently urged sociologists to "stop waiting for historians to provide them with 'data' from which to generalize, and learn the tools of historical research [because] generalizations are far more convincing when based on more, not less, primary data."46Although few generalizations are offered in this study, the arguments presented are based on archival research undertaken at the India Office Library and Records, London. In view of the time span covered, reliance on only primary sources would have been impossible, and, as will be evident from the notes, this study relies heavily on a wide range of secondary sources.

Notes

1. Karl Marx and Frederick Engels, 1974: 68990.

2. C. Wright Mills, 1980: 162.

3. Philip Abrams, 1984: x, 2.

4. Anthony Giddens, 1984: 35758.

5. Benjamin Nelson, 1987.

6. Sociological analyses of science informed by the constructivist and relativist perspective are prolific. Some representative studies include: Bruno Latour and Steve Woolgar, 1979; Karin Knorr-Cetina, 1981; David Bloor, 1976. For examples of attempts to push the relativist perspective to extremes, see Woolgar (1988) and Malcolm Ashmore (1989). For a recent critique of this "reflexive turn," see Zaheer Baber, 1992.

7. Good overviews and critical discussion of the various perspectives in the sociology of science can be found in Barry Barnes, 1974; Michael Mulkay, 1979; Mulkay and Knorr-Cetina, 1983; Susan E. Cozzens and Thomas F. Gieryn, 1990; Andrew Pickering, 1992; Randall Collins and Sal Restivo, 1983.

8. Restivo, 1984.

9. Thomas Kuhn, 1992: 9.

10. Gieryn, 1982: 280.

11. Two studies come to mind: Ashmore, 1989, and Mulkay, 1985. For critiques of the reflexive turn see: H. M. Collins and Steven Yearley, 1992, and Baber, 1992.

12. Woolgar, 1988: 2024.

13. Mulkay, 1979.

14. Knorr-Cetina and Mulkay, 1983.

15. Barnes, 1974: 7.

16. Mulkay, 1979: 61.

17. Woolgar, 1988: 53.

18. Ibid., 54.

19. Ibid., 65.

20. Ibid., 83; 102.

21. See Ashmore, 1989, and Ashmore, Myers, and Potter, 1995. However, the reflexivists and advocates of "new literary

forms" are showing signs of getting tired of their own stylistic tricks. After promising to revolutionize sociological analysis through his new method, Mulkay has reverted to more "traditional" modes of writing and analysis. See Mulkay, 1993; 1994a; 1994b. For critiques of the reflexive turn and the general route some contemporary sociologists of science have taken, see C. Doran, 1989, and Raymond Murphy, 1994.

22. There is a burgeoning literature on this debate. more recent discussions include: Kyung-Man kim, 1992; 1994a; 1994b; Donald T. Campbell, 1989; Roy Bhaskar, 1989; Gieryn, 1982; Restivo, 1993.

23. Kim, 1992: 446.

24. Ibid., 461.

25. For an explicit critique of Bhaskar's critical realism, see Latour and Woolgar, 1979.

26. Bhaskar, 1989: 180.

27. Ibid., 25.

28. Yearley, 1988: 184.

29. Chandra Mukerji, 1989.

30. Stephan Fuchs, 1992; For a critique of radical constructivism, see Robert Hagendijk in Cozzens and Gieryn, 1990.

31. Donald MacKenzie, 1990.

32. Gieryn, 1982: 281.

33. Robert K. Merton, 1970 [1938].

34. Edgar Zilsel, 1941.

35. An exception is the recent study by Toby E. Huff, 1993.

36. Restivo, 1988.

37. Abrams, 1982: 1.

38. Joseph Needham, 1969 177.

39. Needham, 1954. For a critical evaluation of Needham's contribution to the sociology of science, see Restivo, 1979.

40. Russell Dionne and Roy Macleod, 1979.

41. Restivo, 1990.

42. Deepak Kumar, 1982; 1990; Satpal Sangwan, 1990; 1991; Susantha Goonatilake, 1984.

43. Goonatilake, 1984; Claude Alvares, 1980.

44. The theme of science and technology as the tools of colonialism dominates the discussion in Daniel Headrick, 1981; a similar argument is advanced by Deepak Kumar, 1990; George Basalla, 1967; the best critical discussion of Basalla's (1967) simplistic model of the role of colonialism in spreading science and technology to nonscientific societies remains Macleod, 1987.

45. Studies in this new but growing field include: Lewis Pyenson, 1985; 1989; 1993; James E. McClellan, 1992; Patrick Petitjean et al., 1992; Paul

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Cranefield, 1991; John M. Mackenzie, 1990; David Mackay, 1985; Lucile H. Brockway, 1979; Deepak Kumar, 1991; Teresa Meade and Mark Walker, 1991; Michael Adas, 1989; Edward Ellsworth, 1991. For a recent debate on the issue of science and imperialism, see Paolo Palladino and Michael Worboys, 1993, and Pyenson, 1993.

46. Ramachandra Guha, 1990: xivxv.

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Science, Technology, And Social Structure In Ancient India

Except a few Brahmins, who consider the concealment of their learning as part of their religion, the people are totally misled as to the system and phenomena of Nature: and their errors in this branch of science, upon which divers important conclusions rest, may be more easily demonstrated to them, than the absurdity and falsehood of their mythological legendsInvention seems wholly torpid among them. No acquisition in natural philosophy would so effectively enlighten the mass of the people, as the introduction of the principles of Mechanics. Every branch of natural philosophy might in time be introduced and diffused among the Hindoos. The communication of our light and knowledge to them, would prove the best remedy for their disorders; and this remedy is proposed, from a full conviction, that if judiciously and patiently applied, it would have great and happy effects upon them, effects honourable and advantageous for us.

Charles Grant, 1792 1

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The Surya Sidhanta is the great repository of the astronomical knowledge of the Hindus. This book is itself the most satisfactory of all proofs of the low state of the science among the Hindus, and the rudeness of the people from whom it proceeds. The observatory at Benares, the great seat of Hindu astronomy and learning, was found to be rude in structure, and the instruments with which it was provided of the coarsest contrivance and construction. Exactly in proportion as Utility is the object of every pursuit, may we regard a nation as civilized. According to this rule, the astronomical and mathematical sciences afford conclusive evidence against the Hindus. They have been cultivated exclusively for the purposes of astrology; one of the most irrational of all imaginable pursuits; one of those which most infallibly denote a nation barbarous; and one of those which it is most sure to renounce, in proportion as knowledge and civilization are attained.

James Mill, 1826 2

The question now before us is simply whether, when it is in our power to teach this language, we shall teach languages in which, by universal confession, there are no books on any subject which deserve to be compared to our own, whether, when we can teach European science we shall teach systems which, by universal confession, wherever they differ from those of Europe differ for the worse, and whether, when we can patronize sound philosophy and true history, we shall countenance, at the public expense, medical doctrines which would disgrace an English farrier, astronomy which would move laughter in girls at an English boarding school

Thomas Babington Macaulay, 18353

The discussion of science and technology in precolonial India can be classified into three distinct narratives. The dominant "colonialist" perspective was articulated by Charles Grant, James Mill, and T. B. Macaulay. With varying degrees of emphases, Grant, Mill, and Macaulay conceived pre-British India as a veritable tabula rasa onto which modern science and technology had to be inscribed as part of the colonial civilizing mission. In fact James Mill explictly

drew upon the Lockean conception of the mind as a tabula rasa to understand precolonial Indian society and culture. Although Grant, Mill, and Macaulay were writing at different periods of colonial rule, they nevertheless shared a common assumption about the rudimentary quality of precolonial science and technology in India. In his magisterial *History of British India*, James Mill devoted a considerable amount of energy in discussing various aspects of Indian science and technology to demonstrate what he perceived to be a serious lack of creativity and technological ingenuity. Mill's evaluation of Indian science and technology was widely shared by T. B. Macaulay, an assumption that was reflected in the latter's reference to Indian "medical doctrines which disgrace an English farrier, astronomy which would be the laughter of girls at an English boarding house." 4Charles Grant, writing during the early phase of colonial rule, went even further in asserting that "except a few Brahmins, who consider the concealment of their learning as part of their religion, the people are toally misled as to the system and phenomena of Nature. Invention seems totally torpid among them."5The motivations for the articulation of such views, an issue discussed in detail later in this book, were diverse.

However, as Grant, Macaulay, and Mill were associated with the highest levels of the colonial administration, their perceptions of Indian society directly influenced the formulation and enactment of a wide range of social policies in India. Thus James Mill's position as the chief examiner at the East India Company in London brought him into direct contact with issues of colonial administration. His multivolume *History of British India* was the official textbook in use at the Company's college at Hailebury and it constituted an essential guidebook for colonial administrators waiting to set sail for India. The influence of Mill's book was particularly evident on T. B. Macaulay's thinking and on the eventual outcome of the Anglicist-Orientalist controversy, which led to crucial shifts in the education policy under Governor-General William Bentinck in the mid-nineteenth century. In fact it was James Mill who had recommended Macaulay to the directors of the East India Company for the post of legal member of the Governor-General's Council.6Mill's influence on the administrative policies enacted in colonial India can also be gauged from William Bentinck's remark, "I am going to British India, but I shall not be Governor-General; it is you who will be Governor-General," and from Jeremy Bentham's comment that "Mill will be the living executiveI shall be the dead legislature of British India."7Even after making allowances for the strong element of rhetoric in these remarks, there is little doubt that Mill's perception of Indian society was extremely influential in the formulation of colonial policies. In this context, the question of the level of science and technology in ancient and medieval India, or lack thereof, became a major issue of contention, conflict, and debate.

The importance accorded to science and technology as benchmarks for measuring the level of "civilization" is not surprising. The nineteenth century

was an era permeated with the spirit of the Industrial Revolutionan event that represented one of the more palpable achievements of the age of the Enlightenment. It was a period that held out the promise of limitless progress through the rational manipulation and control of the natural world with the aid of science and technology. It is hardly surprising, then, that in their evaluation of "the people without history," 8European colonial powers relied on "machines as the measure of men"9and civilization. Such views, already prevalent during the onset of colonial rule, became dominant during the height of British colonialism in India. The importance of paternalistic inculcation of modern science and technology was increasingly being offered as the raison d'être for the prolongation of colonial rule in India. According to the dominant colonialist discourse, the perceived lack of modern science and technology symbolized societal immaturity and an absence of social responsibility. The self-imposed responsibility of rectifying the situation provided the ideological justification for the continuation of empire. The remark of a colonial administrator who asserted "when India can do her own engineering work, then and only then will she be able to govern herself"10captures the essence of the deployment of imageries from the realm of science and technology to provide ideological support for continued colonial rule.

There was, however, another narrative that emanated from within the colonial administration and that questioned the dominant colonialist perspective on the state of science and technology in precolonial India. William Jones, Prinsep, Colebrooke and other British administrators and scholars associated with the Asiatic Society of Bengal adopted quite a

different viewpoint on the issue. Unlike Grant, Mill, or Macaulay, these administrator-scholars, also known as the "Orientalists," had mastered a number of classical Indian languages, which enabled them to study and translate a wide range of ancient treatises on mathematics, astronomy, and medicine. On the basis of detailed studies of these texts, the Orientalists arguedsometimes in quite an uncritical and exaggerated mannerthat ancient Indians had made significant advances in a number of scientific fields, which could be preserved and developed further only through a continuation of the vernacular system of education. The researches of the Orientalists had led them to a number of discoveries about the degree of sophistication in mathematics, astronomy, chemistry, and medicine in ancient India, and *Asiatic Researches*, the journal of the Asiatic Society, had already started publishing some of these findings in the late eighteenth and early nineteenth century. It was this fact that had enabled William Jones, a Supreme Court judge, the founder of the Asiatic Society, and an enthusiastic botanist, to declare in 1786 "what their astronomical and mathematical writing contain, will not, I trust, remain long a secret: they are easily procured, and their importance cannot be doubted."11Much later, during the Anglicist-Orientalist controversy over the introduction of English as the medium of instruction in European sciences in India, another

Orientalist, H. T. Prinsep argued that the natural philosophy of Bacon, Locke, and Newton had their roots in ancient Indian scientific thinking, and the best way to introduce western science in India would be through the vernacular system of education, which would preserve a sense of historical continuity and individuality. 12However, even William Jones, an ardent admirer of Indian accomplishment who went to the extent of declaring that the ancient Indian texts had anticipated all the metaphysics and philosophy of Newton, argued that the "Asiatics" were "mere children" in comparison to the scientific Europeans.13While the politics and the outcome of the Anglicist-Orientalist controversy will be examined later, suffice it to emphasize that the continuing debates over the level of science and technology in precolonial India contributed to the formulation of colonial policies and influenced the modes and patterns of the exercise of colonial power.

Finally, proponents of a third perspective drew on the findings of the Orientalists to make exaggerated claims about the state of science and technology in ancient India. Constituting a mirror image of the perceptions of Grant, Mill, and Macaulay, proponents of this "nationalist" view claimed that all the discoveries and findings of modern science and technology had been anticipated in ancient India. An example of such an uncritical, yet not uncommon approach, is the assertion that "another remarkable and astonishing feature of the Hindu science of war which would prove that the ancient Hindus cultivated every science to perfection, was that the Hindus could fight battles in the air."14This claim was supported by the arguments of another writer who contended that "to be so perfect in aeronautics, they must have known all the arts and sciences relating to science, including the strata and currents of the atmosphere, the relative temperature, humidity and density and the specific gravity of the various gases."15In such hyperbolic and imaginative reconstructions of past glories, the actual accomplishments of ancient and medieval India in the area of science and technology were obscured from view. Indeed the main motivation for such obviously dubious claims was political rather than academic. Such a perspective provided fuel for retrospective ideological reconstruction of an "imagined community," which was apparently destroyed by the onset of what was perceived to be "Muslim" rule and, later, British colonialism. Such a narrative, fueled by recent political developments, continues to thrive as is evident from the recent Congress on Traditional Sciences and Technologies of India.16A recurring subtheme of this perspective is the argument that the development of indigenous science and technology came to an abrupt end sometime in the twelfth century A.D. According to one commentator, "the history of the progress and civilization of that nation (the Hindu) closed with the end of the twelfth century. Every work that has the stamp of originality had been written before the close of that century."17The argument here is that the onset of "Muselim" rule inaugurated the Dark Ages for medieval India when all scientific and technological innovation came to a

standstill. Another variation on the same theme credits the British colonialists for rescuing traditional Indian science and technology from the debilitating impact of "Muslim rule."

Keeping these three distinct narratives in mind, the purpose of this chapter is to provide a coherent reconstruction of the changing levels of science and technology in ancient India. The third perspective should caution us from deploying

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modern conceptions of "science and technology" to evaluate the past. In the ancient period, science did not constitute an analytically distinct domain, but was intimately interwoven with the other institutions of society. In fact, the term "scientist" was coined by the English naturalist William Whewell only in the mid-nineteenth century, and it is hard to conceive of science as occupying a distinct institutional space or scientists constituting a specialized profession in the ancient period in any part of the world. Finally, in the ancient and medieval periods, the distinction between "science" and "technology" was not as pronounced as it appears to be in the contemporary world. In most cases, science and technology were interwoven and embedded in wider social and cultural contexts. Indeed, even though not everybody would accept his view, Bruno Latour has argued this to be the case for contemporary societies as well, and has coined the term "technoscience" to describe "all the elements tied to the scientific contents no matter how dirty, unexpected or foreign they may seem." 18

Science, Technology, and Social Structure in Ancient India

The Earliest Agricultural Communities

A good starting point for the discussion of ancient "India"19is the Indus Valley civilizational complex, the main contours of which began to take shape in the second half of the fourth and early third millennium B.C.20Archaeological evidence suggests that Mehrgarh, the earliest settlement in the Indian subcontinent, dates from the preceramic Neolithic period or c. 80005000 B.C. According to Bridget and Raymond Allchin, two of the most authoritative archaeologists in the region, at the close of this period mud brick architecture, cultivation of wheat and barley, domestication of cattle, sheep, and goats, and the first evidence of the cultivation of cotton (*gossypium*) had already developed. This period was followed by the ceramic Neolithic period, when comparable settlements existed at several places in the western part of the subcontinent. The third period at Mehrgarh, which lasted until c. 3500 B.C., shows a greater use of pottery and the first introduction of copper tools. In other parts of the subcontinent like the north Deccan, the Ganges Valley, and

the southern Deccan, similar settlements have been excavated. Apart from these settlements, other regions of the subcontinent do not present evidence of settled agricultural communities and were probably inhabited by hunting and gathering and pastoral Mesolithic communities. According to the Allchins, "one of the most striking things about both these early periods is that trade links with the Arabian Sea Coast and with Central Asia seem already to have been established." 21

The Early Indus Valley Civilization

Around the second half of the fourth and early part of the third millenium B.C., a number of factors led to the development of the Indus Valley civilization, which contributed to the social and cultural foundation for the later classical and modern Indian civilization. The early period of the Indus Valley civilization exhibited what archaeologists have termed "incipient urbanism,"22which was largely a consequence of the growth of population and technology and the accumulation of agricultural surplus. Trade and commerce with central Asia and the Indo-Iranian borderlands may also have stimulated some of the developments leading to incipient urbanism. Extensive excavations at a number of sites reveal a degree of planning in the layout of the towns of the Indus Valley. A number of sites reveal wide roads, sun-dried mud brick houses divided by narrow lanes, clearly demarcated burial grounds and cemeteries. Some sites provide indications of buildings used for specialized craft activities.23For example, at the Kalibangan site, potlike hearths are found in some the rooms, and one room contains a series of ovens, both above and below the ground.24

A distinctive feature of all these sites is the presence of massive brick walls surrounding the settlements, presumably as a defense against the constant floods from the Indus and other rivers in the area. Although mud bricks have been excavated from many of the sites from this period, it is at Kalibangan that burnt bricks appear to have been used for the first time. And unlike other sites where irregularly sized bricks were common, the burnt bricks of Kalibangan were standardized and conformed to the ratio of 3:2:1. There is also plenty of archaeological evidence for kilns with separate fire and kiln chambers at Kalibangan. The development of burnt bricks represents a technological advance over the mud bricks, which were probably not very effective against the constant flooding. Other archaeological artefacts such as terracotta figurines depicting animal and human deities; plain and painted clay pottery carrying stylized plant and animal motifs; a number of seals; copper/bronze tools, turquoise and lapis lazuli beads; cattle, sheep, and goat bones; and a number of burial sites provide a glimpse of the material and ideational culture of the period. Although direct evidence is not available, extensive

technological examination indicates that the elaborate pottery of the period was predominantly

fabricated by means of footwheels. 25Another significant find of this period consists of a ploughed field surface with furrows in two directions, suggesting the use of perishable wooden ploughs for agriculture.26

The Mature Indus Civilization

The gradual growth in population, further development of technology and agricultural techniques, and the expansion of socioeconomic interaction through the preexisting trade links with central and west Asia contributed to the transition from "incipient urbanism" to the mature Indus Valley civilization.27Comprising a number of well-known settlements like Harappa, Mohenjo-daro, Kalibangan, Lothal, etc., the mature Indus Valley civilization covered a little less than half a million square miles and lasted for about five centuries as a distinct cultural entity. As a number of archaeologists have pointed out, such a large civilization complex indicates that the relationship between the city-centered communities of agriculturalists and craftsmen, and those who provided the means of transport and communication, must have been a relatively stable one, indicating a strong and firmly based system of authority that held them together and maintained their relations. Although the details of the system of political authority are still not clear, Allchin and Allchin contend that there can be no doubt of its existence and argue that it "represented a special achievement in the world of the third millennium B.C. a time when in other parts of the world the largest effective unit was little more than the city state."28

The foundational component of the classical and even modern south Asian culture and society can be traced to the Indus Valley period. The influence of this period is especially evident in the sphere of religious beliefs and rituals. There is also some archaeological and literary evidence that suggests that some of the scientific texts recorded in the later classical period originated in the Indus Valley civilization. In view of the enormous importance and significance of the Indus Valley civilization for later south Asian culture, the main purpose of this section is to reconstruct the social and material life of the period with the aim of clarifying the manner in which these factors facilitated specific technological developments and the emergence of early scientific thinking, especially in astronomy and mathematics.

The settlements of the Indus Valley, although spanning a very large area, exhibited a high degree of cultural uniformity. Almost all of the excavated urban centers display broadly similar patterns and geographical orientation consisting of two distinct elements. To the west there is a "citadel" mound built on a high podium of mud brick, with a long axis running north-south, and to the east there is the "lower" town or the main residential area. The whole complex or city is surrounded by massive brick walls with entrances at the north and south ends. The principal streets run across the residential area

of the city from north to south. There is a general coordination of the measurements of the streets, the largest being twice the width of the smaller, and three or four times that of the side lanes. In the vicinity of the citadel mound are buildings that appear to be sites of civic, religious, and administrative functions. The general population probably resided in the lower part of the town. 29

There was standardization in the size of bricks at all sites, the predominant size being 28 by 14 by 7 cm., or a ratio of 4:2:1. At Kalibangan, sun-dried bricks appear to be more common, with burnt bricks being exclusively reserved for use in the construction of wells, drains, and bathrooms. Some bricks of specialized shapes, such as wedge-shaped ones used in the construction of wells, have been excavated. Timber was used for the construction of flat roofs, and, in some cases, it was also utilized for a semistructural frame or lacing for brickwork.30

There was significant variation in the size of residental houses, which range all the way from single-room tenements to units with courtyards and up to a dozen rooms of various sizes, to much larger houses with several dozen rooms and several courtyards. The existence of these variations in the size of the houses provides indirect but clear evidence of the presence of distinct strata or classes. Almost all of the houses had private wells for water supply, and most had brick stairways leading to the upper stories. Hearths are commonly found in the rooms and almost every house had a bathroom. In some cases, there are indications of bathrooms on the first floor. The bathrooms are identifiable by their

connection via a drainage channel to chutes built into the thickness of the wall, giving access to the main street drains. A number of pottery drainpipes have also been recovered, and many of the streets and lanes had brick drains, covered over by bricks or stone slabs into which the house drains flowed. The existence of some form of civic or municipal authority that presumably coordinated their regulation and maintenance can be inferred from the presence of extensive networks of sophisticated drainage systems at almost all the sites.

Excavations of the lower town have also unearthed a wide range of craft workshops, identified by the presence of potters' kilns, dyers' vats, metal tools, deposits of beads, etc., indicating a degree of technological specialization and social stratification. The extensive finds of artifacts at Mohenjo-daro indicate the presence of specialized groups of craftsmenpotters, copper and bronze workers, stone workers, builders, brick makers, seal cutters, bead makers, etc. The presence of other groups or strata like the priests, administrators, sweepers, traders, etc. is also implied. Evidence of the extensive practice of agriculturethe discovery of furrowed fields, deposits of wheat, barley and rice husk, and the large granaries found at some sites, especially at Harappaindicates that these preindustrial urban settlements were supported by the agricultural surplus. Together with these food crops, there is ample evidence of the cultivation and weaving of cotton. Allchin and Allchin have argued that woven cotton textiles were already in a mature stage of development, and evidence for its cultivation

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has been found at the Mehrgarh site, which existed almost two thousand years earlier than the mature Indus Valley civilization. The existence of cotton textile weaving during the Indus Valley period can also be inferred from the impressions of textiles upon the earthenware and pottery found at the Harappan sites. 31It is probable that cotton textiles, together with beads and other articles, were involved in the trade with the central and west Asian regions, and the extensive urban settlements were probably supported by this trade.

Closely linked with trade is the issue of the method and mechanism of transportation. Some circumstantial evidence of maritime trade is provided by the representations of ships found on seals or as graffiti at a number of sites. A terra-cotta model of a ship, with a socket for the mast and eyeholes for fixing rigging has been found at Lothal.32There is ample evidence of the mode of inland transportation and a number of terra-cotta models of bullock carts. Copper and bronze models of carts with seated drivers have also been found. At a site called Daimabad, a number of elaborate solid-cast copper models of various transportational devices from the late Indus period (c. 18001500 B.C.) have been recovered. One of the objects is quite elaborate, consisting of a two-wheeled chariot with a standing rider. The chariot is attached by a long pole to two yoked oxen, which stand on two cast copper strips. These artefacts display a high degree of metallurgical skill in casting and designing and provide some indication of the level of technological sophistication attained in that period.33Finally, in a number of roads and streets of the cities, extensive cart tracks have been discovered, providing evidence of local transportation networks in the urban areas.34

Metrology In The Indus Valley

Extensive trade during the period provided the stimulus for the development of an elaborate system of weights and measures. Archaeologists have attempted to reconstruct the system of metrology of the Indus Valley from the vast number of weights and measures found at most of the settlements.35Made of polished shale, the weights were found to be in units of 0.8565 grams each.36These weights proceed in a series, first doubling from 1, 2, 4, 8 to 64, then going to 160; they then proceed in decimal multiples of sixteen: 320, 640, 1600, 3200, 6400, 8000, and 128,000.37Together with stone weights, balances consisting of a bronze rod and suspended copper cups have also been found at some sites.38At Mohenjo-daro, a piece of a larger measuring device with regular gradations in subgroups of five divisions has been discovered, providing indication of the use of linear measurements probably employed for construction work. Other instruments, possibly employed for the measurement of angles, have also been discovered at a number of sites.39It is unlikely that the planning and construction of such elaborate architectural structures like the "Great Bath" excavated at Mohenjo-daro or the meticulous laying out of roads at right angles would have

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been possible without accurate methods for measuring angles. All these findings suggest that extensive trade stimulated

the development and refinement of a complex system of weights and measures in the mature Indus period.

Finally, such a complex civilization would not have been possible without some form of written communication. While some writing may have been practiced on perishable materials that could not have survived, the discovery of over four thousand seals at Mohenjo-daro and other sites have provided some clues about the writing practices and inscriptive devices of the period. The seals, which consist of elaborate inscriptions and pictograms representing various animals and trees, are made of steatite, and the normal type is square, having one line of text at the top of the face with a pictorial motif beneath it. Although most of the seals were probably used for communication, some of them seem to have been used for marking clay tags, which were then attached to bales of goods. Traces of packing materials on the reverse side of the clay tags have also been found. 40

The Indus Seals And Astronomical Thinking

In addition to the light the Indus seals shed on the technique and mode of communication, they are also significant for the reconstruction of the development of scientific thought in that period. A Finnish team of archaeologists led by Asko Parpola has been attempting to decipher and reconstruct the elements of an astronomical system in a group of Indus seals.41Although the process of interpreting the seals is still underway and the findings to date are quite tentative, Parpola and his associates have utilized the homonymy between the Dravidian word *min*, which stands both for "fish" and "star," and is derived from the verbal root *min*, which means "to glitter," to interpret a number of pictograms on the seals. Pictorial representations of fish and stars in combination have been interpreted to denote particular constellations. According to Parpola, numbers preceding the fish sign give such readings as, for example, "constellation consisting of six stars," which is taken to refer to the constellation Pleiades. Such an interpretation is consistent with the most ancient Tamil texts of the first century A.D., which refer to the constellation Pleiades as *aru-min* or "six star."42Using a similar methodology of relying on homonyms, Parpola and his colleagues have interpreted the depiction of a number of planets on the Indus Valley seals. Their list includes Jupiter, Venus, Mercury, Saturn, and Mars, which also constitute the five planets explicitly discussed in a later period of antiquity in India.43

Parpola supports his thesis about the presence of an astronomical system in the Indus Valley civilization by linking his findings to the religious practices, philosophy, and cosmology of ancient India. For example, the practice of naming a child after the constellation under which it was born and of carefully defining the position of the planets in the natal horoscope has existed at least as early as the time of the Buddha. The ancient *Rgvedic* hymns (c. 1400

B.C.) frequently refer to the lunar calendar *nakshatra*, which is very similar to the Chinese *hsiu* calendar. Both, according to Joseph Needham, can be dated to c. 2400 B.C. 44According to Parpola, the *nakshatra* calendar, which is based on principles quite different than those of ancient Greece and Egypt, is likely to have originated in the Indus Valley civilization. The date of its composition, which is not in doubt, coincides with the height of urbanization in that area. There was no urban civilization in China during that period, and the calendar could not have been borrowed from either Egypt or Greece as it is based on a distinctly different principle. As Joseph Needham explains it, while Egyptian and Greek calendars of antiquity were based on observations of the "heliacal risings and settings" of stars at dawn and dusk, the *nakshatra* or *hsiu* calendar of India and China were based on the method of opposability, or observations of the stars that lay opposite the sun.45These factors, coupled with the fact that the Indus valley civilization was definitely the oldest urban civilization in the Asian region, enable Parpola to contend that elements of a protoastronomical system can be discerned in the earliest period of ancient India. The argument is supported by the fact that the plans of the cities of the Indus Valley, especially Harappa, demonstrate that they were built on a grid pattern and carefully oriented according to the cardinal directions which must have been obtained by some astronomical observation.46For Parpola, the fact that the ancient cities were carefully planned and accurately oriented to the cardinal directions presupposes the use of gnomon and some practical knowledge of rudimentary geometry.47Such an assertion is supported by references to the gnomon (*sanku*) in the corpus of text known as the *Sulbasutras*, which originated during the Indus Valley period and is discussed below in some detail.48

Although Parpola's arguments are based on extensive material evidence, he has not claimed the final word on the issue. On the contrary, he has repeatedly emphasized the tentativeness of his findings. However his argument for the presence of a rudimentary astronomical system in the Indus Valley period has been followed up by a number of scholars who have attempted to further develop the outlines of the system by bringing together new, albeit fragmentary evidence within a

similar interpretive framework.49Although the task of interpreting the Indus Valley seals is still in progress, most historians agree on a high degree of cultural continuity between the Indus Valley civilization and the later Vedic period. In the next section, some continuities in the scientific tradition are traced, and the social and cultural context of the development of mathematics and geometry in ancient India is analyzed.

Religion, Social Structure And The Origins Of Geometry And Mathematics

The development of protoscientific ideas in ancient India was intimately connected with the larger social, cultural, and especially religious context.

This relationship between certain religious rituals, practices, and scientific ideas is especially evident in the development of geometrical, mathematical, and astronomical ideas preserved in the *Sulbasutras*. 50Composed and systematized sometime between 800 and 600 B.C.,51the *Sulbasutras* constitute one of the appendices or *Vendagas* of the main corpus of the *Vedas*, and represent the oral tradition for the transmission of knowledge in ancient India. The *sutras* are well adapted for this tradition as they constitute a specific form of composition, which emphasizes brevity and uses a specific poetic style to capture the essence of an argument. To facilitate memorization of large numbers of verses, the use of verbs is avoided and nouns are compounded.52The term *Sulba* refers to "rules" relating to sacrificial rites as well as the rope or cord used for measuring the sacrificial altars. The main text of the *Sulbasutras* consists of rules and instructions governing the measurement and construction of sacrificial altars for the execution of particular religious rites and rituals. These instructions laid the groundwork for the emergence and refinement of geometrical and mathematical thinking in ancient India. The connection between religious rituals and the development of protomathematics and geometry lies in the imperative to ensure strict conformity with the Vedic scriptures regarding the exact size, shape, and orientation of the sacrificial altars to be constructed.

In order to ensure the efficacy of specific rituals, the construction of altars had to conform to precise specifications regarding their forms and patterns. The shapes and sizes of the altars varied according to the type of religious rituals to be performed. Thus, the *Sulbasutras* recommend square and circular altars for rituals performed in the privacy of the household, while more complex altars whose shapes represent combinations of rectangles, triangles, and trapeziums were required for worship in the public sphere.53One of the most complex altars was shaped like a falcon, and it was believed that performing a ritual sacrifice on such an altar would enable the soul of a person to be conveyed by a falcon straight to heaven. In the words of the text of the *Sulbasutras*, "He who wishes for heaven, may construct the altar shaped like a falcon; this is the tradition."54The falcon-shaped altar, or the *vakra-paksasyena-citi*, was to be constructed of bricks. A number of intricate geometrical calculations were required to attain the exact specifications of size and shape.55Another complex form of altar was the *sara-rathacakra* which was shaped like a chariot wheel with spokes, and whose construction required intricate geometrical calculations and the manufacture of a wide variety of bricks conforming to specific shapes and measurements.56

The *Sulbasutras* provide a number of examples where considerable geometrical calculations are required for the construction of specific sacrificial altars. One of the problems was the construction of altars of a variety of shapes that covered the same area. Another problem was the construction of two altars so that the first would cover exactly twice the area of the previous one. It was in the attempt to meet these religious and ritual imperatives of converting

one shape to another or of simply doubling the area covered by an original altar that knowledge of intricate geometrical operations evolved and was recorded in the *Sulbasutras*. For example, the essence of the Pythagorean theorem is captured in the following *sutras*, or set of instructions:

> The cord which is stretched across the diagonal of a square produces an area of double the size (of the original square).
>
> The cord in the diagonal of a square is the cord (the line) producing the double (area). 57

Although the *sutras* above represent instructions for constructing square-shaped altars twice the size of the original one, the geometrical reasoning behind them is not hard to discern. It can be expressed in more familiar terms as "the square of the diagonal of a square is twice as large as that square."58The corpus of the *Sulbasutras* contains numerous other instructions that display a good grasp of basic geometrical and mathematical operations and rules. These include problems such as "merging two equal or unequal squares to obtain a third square," "transforming a rectangle into a square of equal area," and "squaring a circle and circling a square."59The solution to the first two problems as provided by the *Sulbasutras* can now be recognized as the Pythagorean theorem. The solution to the last problem, that of converting a circle into a square so that both have the same area, cannot be achieved exactly, but the *Sulbasutras* provide answers that represent remarkably close approximations. For converting a circle into a square, so that their areas are approximately the same, the solution provided in the text is: "Divide the diameter into 15 parts and take 13 of these parts as the side of the square."60

One striking feature of the *Sulba* text is the discussion of a procedure for ascertaining the square roots of irrational numbers, or "surds," to a very high degree of accuracy. Once again, the need to construct a square sacrificial altar twice the area of another square altar, gave rise to a geometrical method of calculating the square root of irrational numbers with the help of the theorem of the square of the diagonal.61Using the method advocated in the *Sulbasutras*, the value of the square root of two comes to 1.4142156, which is remarkably close to the actual value of 1.414213.62

Overall, the *Sulbasutras* provide a striking example of the intimate interconnections between the larger socioreligious context and the development of geometrical and mathematical knowledge in ancient India. Not much is known about the authors who inscribed the oral verses as texts, but from the nature of the problems being tackled, it is probable that they were not just scribes or mathematicians, but priest-craftsmen executing a wide range of tasks, which included the construction of *vedi*, or sacrificial altars, maintaining *agni*, or sacred fires, and instruction of worshippers on the proper choice of

sacrifices and altars. 63Although there are many versions of the texts, those recorded by Baudhayana, Apastamba, and Katyayana are best known for their mathematical and geometrical content.64However these three priest-scholars only recorded particular versions of the *Sulbasutras*, which probably had collective authors and had been preserved and transmitted orally from another period. In fact, these texts provide one of the major connecting cultural and scientific links between the earlier Indus Valley civilization and the later Vedic period of the first millenium B.C.

Although there are no traces of the *Sulbasutras* from the Indus Valley civilization, the fact that a major portion of the text consists of instructions for the construction of sacrificial altars from kiln-fired bricks makes it improbable that they originated during the later Vedic period. Society in the early Vedic age was predominantly pastoral in nature, and as there was no urban civilization or brick manufacture before the Indus Valley period, it is unlikely that the *Sulbasutras* could have originated in any other period. However, it was in the Vedic period that the *Sulbasutras*, transmitted from the past, were recorded and systematized in at least three distinct versions. All available archaeological evidence suggests that the Sulbasutras originated during the Indus Valley period and were transcribed by a number of authors in the later Vedic period.65

Religion and Astronomy in Ancient India

As in the case of mathematics, developments in astronomy were closely related to certain imperatives deriving from religious beliefs and practices prevalent in ancient India. The requirements for certain religious practices, especially the need to determine the accurate time for the performance of sacrifices, provided a degree of institutional stimulus and support conducive for sustained interest in the systematic study of celestial bodies.66

The fact that accurate timing was crucial for the observation of various rituals and sacrifices led to an early concern for devising a system of division of time by observing the movement of the sun and moon. The earliest system devised for this purpose consisted of the *naksatras*, or the "lunisolar" calendar. As discussed in the *Rgveda*, which constitutes just one segment of the larger corpus of the *Vedanga Jyotisa*, or "ancillary Vedic astronomy," the moon's path was divided into twenty-seven equal parts as it took about twenty-seven and one-third days to complete a full cycle. These twenty-seven parts of the complete cycle, together with the stars and constellations lying in the path of the moon's trajectory, were called *naksatras*.67The delineation of these *naksatras* was intimately connected with ascertaining the proper times

for the performance of certain religious rituals. For example, another set of religious texts, the *Satapatha Brahmana* refers to a ritual that requires fire and recommends the *Krttika* (the star Eta Tauri of the Pleiades group) as the *naksatra* or lunar asterism under which this ritual should be performed.68The *Rgveda* has

detailed discussions of a number of constellations and five planets; two of the major planets are specified as *Brhaspati* (Jupiter) and *Vena* (Venus). 69The same text also identifies the sun as the cause of changes in the seasons, and it describes the moon as *Surya-ras'mi*, or one that shines due to the light of the sun. Finally, the *Rgveda* identifies some constellations other than the *naksatras*, or asterisms, and these include the Great Bear, Canis Major, and Canis Minor.70

Two other texts, the *Yajurveda* and the *Atharvaveda*, which together with the *Rgveda* constitute the corpus of the *Vedanga Jyotisa*,71are manuals that contain instructions for computing the civil calendar and the proper times for the performance of rituals.72Although these texts did not set out astronomical formulations for their own sake, they provide a good glimpse of the astronomical basis for the hymns contained in them. Some knowledge of calendrical science is evident in the full treatment of *gavam ayana* and other sacrifices of different durations based on the daily progress of the sun. The equinoxes and solstices are calculated accurately for the purposes of religious rituals, and the daytime has been divided into two, three, four, five, and fifteen equal parts, each division having a different nomenclature. Finally, another text from the same period, the *Taittiriya Brahmana* praises *naksatra-vidya*, or the "science of stars," and refers to a hierarchy of scholars who cultivated that knowledge. Frequent references are also made to groups of people who are termed as *naksatra-darsa*, or "star-gazers," and *ganaka*, or calculators.73

Without going into detail about the elements of protoastronomical thinking in the Vedic texts,74it should be reiterated that much of the concern with the movements of celestial objects was shaped by religious considerations. Another point worth emphasizing is that although these religious hymns were recorded during the Vedic period, they represent a tradition that originated much earlier in the preceding Indus Valley period. Like the *Sulbasutras*, the development of the calendrical system of the *naksatras* presupposes an urban civilization and society during the Vedic period that was predominantly pastoral. The origin of the *naksatras* has been dated by a number of scholars to about 2400 B.C., which locates it during the height of the Indus Valley period.75Excavations at some of the key Indus Valley sites, especially Kalibangan, have revealed a number of fire altars. These findings concur with the contents of some of the Vedic literature, which includes manuals for a wide range of religious rituals. Although these rituals originated in pre-Vedic times, they must have undergone a number of modifications and transformations before being recorded during the Vedic period. Overall, concern with making sure that the religious rituals were performed at correct and auspicious times provided the impetus for observation and calculation of the movements of celestial objects and laid the foundations protoastronomy in ancient India. These factors contributed to the evolution of both astronomy and mathematics in the post-Vedic period, developments that are discussed in the following section.

Astronomy and Mathematics in the Post-Vedic and Early Medieval Period: The Siddhantas, Trigonometry, and Algebra

There was a gap of a few hundred years between the Vedic period and the first millennium A.D., when the works of some major Indian astronomer-mathematicians like Aryabhata, Brahmagupta, Sridhara, and Bhaskara I and II appeared. During the intervening period, the development of astronomy and mathematics declined dramatically due to a number of factors. The virtual disappearance of Vedic sacrifices presumably led to a loss of interest in geometry and mathematical calculations as there were no altars to be constructed. 76The mode of preservation and transmission of this knowledge was another factor that contributed to its decline after impressive beginnings. Originally the mathematical and astronomical ideas in the Vedic period were preserved orally in the form of *sutras*, or hymns. Even when they were transcribed, they were accessible only to the intellectual elites. As some scholars have argued, such a mode of knowledge accumulation and transmission confined these intellectual pursuits to a tiny elite whose existence depended on continued patronage.77

On the whole, mathematical and astronomical knowledge of the post-Vedic period represented a slight shift away from its earlier dependence on religion. Although astronomy and mathematics were not entirely disconnected from religious

concerns, this period witnessed the resurgence of concentrated effort at studying and calculating the velocities, or *gatis*, and trajectories, or *vithis*, of the five planets, which were known since Vedic times.78These calculations had already been undertaken, albeit crudely, in the earlier Vedic period and recorded in the *samhitas* and *puranas*, but it was only in the post-Vedic period that a sustained effort at systematization produced what has come to be known as *Siddhantic* astronomy.

During the phase of *Siddhantic* astronomy, various schools of mathematician-astronomers flourished, and many astronomical texts were composed. The most well known of these texts is the *Surya Siddhanta*,79which was composed in c. 400 A.D. and judged by James Mill to be an indicator of the low level of Indian civilization. The scholars of this period paid explicit attention to many aspects of planetary motion and devised mathematical and algebraic methods to facilitate their calculations. As a consequence, the symbiotic relationship between mathematics and astronomy, already evident in the earlier periods, was further reinforced and strengthened. Planetary positions were computed, eclipses calculated with the results corrected for parallax, and a wide range of mathematical techniques, including plane and spherical trigonometry and applications of indeterminate equations, were applied in making these calculations.80More specifically, the individual chapters of the *Surya Siddhanta* deal with: (I) the mean motions of the planets, (II) the true position of the planets, (III) direction, place, and time, (IV-VI) the nature of

eclipses, (VII) planetary conjunctions, (VIII) asterisms, (IX) heliacal risings and settings, (X) the rising and setting of the moon, (XI) "certain malignant aspects of the sun and moon" treated astrologically, (XII) cosmogony, geography, and the "dimensions of Creation," (XIII) measuring instruments, such as the armillary sphere, clepsydra, and gnomon, and (XIV) different ways of reckoning time. 81It is the astrological dimension of this work that attracted negative comments from James Mill as it did not meet his criterion of utility.

The Indian Roots of Trigonometry

A key innovation arising from the *Surya Siddhanta* was the use of the sine (*jiva*) of an angle, leading both to the development of trigonometry and a trigonometrical tradition in astronomy. The mathematician-astronomer Aryabhata seems to have been the first to use the term *jiva* when he provided a table of "sines," "versed sines," and a formula for calculating these. Bhaskara further developed the concept of *jiva* by providing a table of sines by degrees. The modern trigonometrical term "sine" has an interesting etymological history. The Sanskrit term *jiva*, which was used by the Indian mathematicians, is an abbreviation of *ardhajiva*, which means "half chord." During the process of cross-cultural transmission through the Arabs, the term was "transliterated into the meaningless Arabic *jiba*, the consonants of which allowed later writers to substitute the word *jaib*, "bay or curve," and this word was translated into Latin as *sinus*," from which term "sine" is derived.82According to Joseph Needham, it was around c. 400 A.D. that "the Indian mathematicians originated trigonometry as we know it."83

Finally, the post-Vedic period provides clear evidence of the development of observational astronomy, as a number of texts from this era, including chapter thirteen of the *Surya Siddhanta* contain systematic discussions of the construction and use of a wide range of astronomical instruments.84Such evidence is significant because, contrary to early assertions about the purely deductive and computational nature of Indian astronomy, these findings confirm the integral role of empirical observation in the early phases of the development of astronomy in ancient India. As will be discussed in the next chapter, this tradition of observational astronomy was further developed in the seventeenth century when gigantic observatories were constructed in five cities, three of which still survive in good condition in New Delhi, Jaipur, and Varanasi.

The major mathematician-astronomer of the early classical post-Vedic period was Aryabhata, best known for his work *Aryabhatiya*85, which was completed in 499 A.D. This work contains details of an alphabet-numeral system of notation, rules for arithmetical operations, and methods for solving simple and quadratic equations and indeterminate equations of the first degree.86The same work also determined 3.416 as a close approximation to the ratio of the circumference of a circle to its diameter and provided correct

general rules for computing the sum of natural numbers, their squares and cubes. Particularly noteworthy is Aryabhata's theory of the rotation of the earth on its axis, although this theory remained isolated and was not followed up by later scholars. 87Aryabhata's writings gave rise to a school of mathematician-astronomers, and his work was cumulative to a certain degree. Two of his more famous followers included Varahamihira (b. 505587 A.D.) and Bhaskara I (b. 600 A.D.) who extended his work in a number of areas. Bhaskara I was one of the most competent exponents of Aryabhata's astronomy and his major contribution to mathematics was his solution of indeterminate equations of the first degree, which, in turn, influenced the work of another school of mathematician-astronomers that included the renowned Brahmagupta.88

Brahmagupta, born in 598 A.D., is best known for his *Brahma Sputa Siddhanta*, a work dealing with astronomy and mathematics, and his *Khanda Khadyaka*, which deals with further developments in algebra and trigonometry, including a method of obtaining the sines of intermediate angles from a given table of sines.89The *Brahma Sputa Siddhanta* is extremely significant as it contains a detailed and systematic discussion of the construction and use of a wide range of astronomical instruments.90The twenty-second chapter of this text contains not only a detailed description of a number of instruments, but also methods of computing various astronomical data from the readings taken with these instruments.91

Brahmagupta and the Origins of the Concept of Power Technology

Some of Brahmagupta's ideas recorded in his *Brahma Sputa Siddhanta* led to an innovation: the concept of power technology. His interest in devising mechanical instruments led to a very early conceptualization of a "perpetual motion machine," a machine that could turn forever without any human agency. Brahmagupta's search for a *perpetuum mobile* led him to design a wheel of light wood, with hollow spokes of equal size inserted at equidistant intervals. Each spoke was to be half-filled with mercury and then sealed. Brahmagupta believed that if the axle of this wheel was set up on two supports, the mercury would run up and down the spokes causing the wheel to turn perpetually, or *ajasram bhramati*.92Brahmagupta's idea of constructing a wheel capable of perpetual motion was based on the belief that mercury could overcome inertia and cause the wheel to turn eternally.

Brahmagupta's conception of a *perpetuum mobile* was pursued by Lalla and Bhaskara II (b. 1114 A.D.), two mathematician-astronomers of a later period who suggested a number of modifications to the original idea. One suggestion for improvement was to construct a wheel with spokes curving in the same direction, which would enable it to turn forever because the mercury would alternatively run towards the nave and rim of the wheel. In the text

Siddhanta Siromani, Bhaskara II provides the following instructions for constructing a *perpetuum mobile*:

> Make a wheel of light wood and in its circumference put hollow rods all having bores of the same diameter, and let them be placed at equal distances from each other; and let them be all placed at an angle somewhat verging from the perpendicular; then half fill these hollow rods with mercury: the wheel thus filled, will, when placed on an axis supported by two posts, turn by itself. 93

In another variation on the theme, Bhaskara II continues, "Scoop out a canal in the tire of a wheel; then, plastering leaves of the *tala* tree over this canal with wax, fill one half of this canal with water and the other half with mercury till the water begins to come out, and then seal up the orifice left open for filling the wheel. The wheel will then revolve of itself, drawn round by the water."94These ideas were probably never put into practice, and may appear to be nothing short of flights of fantasy, relying on alchemists' notions of the magical qualities of mercury. However as the historian of science Lynn White Jr. has pointed out, such fantasies are significant in the history of ideas, and the conception of perpetual motion, originating in India, probably laid the foundation for an important innovation in Europe.95In his *Medieval Technology and Social Change*,96White has traced the transmission of Bhaskara II's version of Brahmagupta's idea of *perpetuum mobile* via the Arab world to Europe, which, under the appropriate social conditions, led to the conceptualization of power technology in the modern world. According to White, Bhaskara II's concept was "almost immediately picked up in Islam where it amplified the tradition of automata."97In the manuscripts of the Islamic thinker Ridwan (circa 1200 A.D.), descriptions of six *perpetua mobilia* appeared, one of which was identical to Bhaskara II's mercury wheel with slanted rods. Two others were identical to the first two perpetual motion devices to appear in Europe (circa 1235 A.D.). An anonymous Latin manuscript of the later fourteenth century contains a description of a perpetual

motion machine very similar to Bhaskara II's second proposal for a wheel with its rim containing mercury. White's extensive research leads him to conclude that "we may be sure that about A.D. 1200 Islam served as intermediary in transmitting the Indian concept of perpetual motion to Europe, just as it was transmitting Hindu numerals and positional reckoning at the same moment."98

The roots of the idea of perpetual motion are attributed by White to the cosmology of ancient India expressed in the "Hindu belief in the cyclical and self-renewing nature of all things."99In a more general sense, "to Hindus the universe itself was a perpetual motion machine, and there seemed nothing absurd in an endless and spontaneous flow of energy."100Although the idea and conception of a *perpetuum mobile* has its origins in seventh-century India, it was under the suitable social conditions of late medieval Europe that it eventually led to the

development of power technology. The concept was firmly embedded in Indian cosmology and originated as nothing more than a fantasy. However, as White has argued, "without such a fantasy, such soaring imagination, the power technology of the Western world would not have developed." 101

Bhaskara And Further Developments In Astronomy And Mathematics

As evident from the above discussion, the work of Aryabhata (b. 476 A.D.) and Brahmagupta (b. 598 A.D.) in the early phases of the first millenieum A.D. provided the impetus for the further development of some key concepts in mathematics and astronomy. Their work stimulated the rise of a number of schools of mathematicians and astronomers who further developed and refined these ideas in a number of texts and treatises, which have survived to the present day. Thus Mahavira (b. 850 A.D.), a member of a mathematical school at Mysore in southern India acknowledges the influence of the work of Aryabhata and Brahmagupta in his treatise on mathematics, *Ganita Sara Samgraha*. This text, which was widely used in southern India and was translated into a number of regional languages during the eleventh century, contains a detailed examination of operations with fractions and solutions for different types of quadratic equations as well as an extension of the earlier work on indeterminate equations. The author of the text also attempts, although unsuccessfully, to derive formulae for the calculation of the area and perimeter of an ellipse.102Sridhara (b. 900 A.D.) composed a mathematical text, the *Pataganita*, which dealt with fractions, with operations like extracting square and cube roots, and provided eight rules for operations involving zero.103His text, together with his method of summation of different arithmetic and geometric series, became a standard reference for the work of later schools of mathematicians and was quoted directly by Bhaskara II two hundred years later.104Aryabhata II (b. 950 A.D.) who was a contemporary of Sridhara, composed an astronomical treatise, *Maha Bhaskariya*, which has a clear discussion of *kuttaka*, or indigenous algebra, and provided solutions to indeterminate equations.105

The work of these earlier scholars was systematized and further developed by Bhaskara II, the mathematician-astronomer of the school at Ujjain under whom the analysis of indeterminate equations reached its zenith. Working in the mid-twelfth century, Bhaskara II authored three major treatises on mathematics and astronomy*Lilavati*, *Bijaganita*, and *Siddhanta Siromani*.106The *Lilavati* represents a further development of the work of Brahmagupta, Sridhara, Aryabhata II, and the *Bijaganita*; it discusses problems related to the calculation of surds, the solution of simple and quadratic equations, and also contains the *chakravala* or "cyclical" method of providing solutions to indeterminate equations of the third and fourth degree, which, according to the historian of science J. J. Winter, has perpetuated Bhaskara II's

name "for all time in the history of the theory of numbers." 107Thus the "cyclical" solution to the general equation

$$ax^2 + bx + c = y^2$$

represents a major achievement by a mid-twelfth-century mathematician. It should be noted that independent European investigation of the same problem did not yield results until the work of Euler and Lagrange around 1770.108Bhaskara II's final work, the *Siddhanta Siromani* demonstrates the application of trigonometrical operations, including the sine tables and the rudiments of infinitesimal calculus, which was further developed in the fourteenth century by the Kerala

school of mathematicians in their work on infinite series.109The same work also provides more refined methods of accurately predicting eclipses, an issue that was extremely significant in view of the religious rituals and sacrifices that had to be performed to counteract the negative and "inauspicious" influences associated with such events. To enable the accurate prediction of eclipses, Bhaskara II provided more precise methods for calculating the instantaneous motion, or *tatkalika-gati*, of the moon, which had already been discussed by Aryabhata I and Brahmagupta.110

The Mathematics Of The Bakshali Manuscripts

Further details regarding the development of mathematics and astronomy in the ancient period come from the "Bakshali manuscripts," found accidentally in 1881 near a village called Bakshali. The manuscripts, now preserved at the Bodelian Library of Oxford University, consist of seventy folios of mathematical writings on birch bark, the composition of which archaeologists have dated to the third or fourth century A.D.111The Bakshali manuscripts deal with with a number of practical and theoretical mathematical operations and problems that include: fractions, square roots, arithmetical and geometrical progressions, income and expenditure, profit and loss, computation of money, interest, the rule of three, summation of complex series, simultaneous linear equations, quadratic equations, and indeterminate equations of the second degree. Significant from the point of view of the history of mathematics is the fact that in the manuscripts nine digits and zero are used with a place value. If the dating of the Bakshali manuscripts is correct, it provides the earliest evidence yet of a well-established number system incorporating the use of zero and place value scale. In addition to the Bakshali manuscripts, there are some twenty inscriptions in India, between 595 A.D. and the end of ninth century in which numerals with place value are used.112The alphabetical notation of Aryabhata I, his method for the extraction of square and cube roots, the numerical words used by Brahmagupta, and the *Surya Siddhanta* imply nine symbols with place value and a sign for zero as early as the fifth century A.D.113

The Indian Numeral System and the Concept of Zero

Most historians of science and mathematics agree that the use of numerals and zero as found in modern mathematics originated from ancient India. 114They are termed Arabic numerals because they were transmitted to Europe through the Arabs in the tenth century and were themselves introduced to the Arabs at about 770 A.D. when Indian scholars brought an astronomical treatise, the *Sindhind* to the court of al-Mansur at Baghdad. There is an earlier reference by a Syrian writer, Severus Sebokt (662 A.D.), who writes of the "subtle discoveries of the Hindus in astronomy, discoveries which are more ingenious than those of the Greeks and the Babylonians, and their clever method of calculation, their computation which surpasses words, I mean that which is made of nine signs."115There was a high degree of commercial, social, and intellectual intercourse between south and west Asia during that period and a number of rulers at Baghdad and other Arab centers patronized Indian mathematicians and astronomers. It was the combination of flourishing trade and commerce and the extension of patronage by some of the rulers in west Asia that facilitated the transfer and rapid adoption of the Indian numeral system by the Arabs. As the historian of mathematics Dirk Jan Struik has argued, in many cases, "Greek merchants became acquainted with oriental mathematics along their trade routes."116

Ancient Indian Cosmology And The Concept Of Zero

The origins of the concept of "zero" represented by the term *sunya* in Sanskrit is rooted in the ancient Indian cosmology. *Sunya*, or *nirguna*, means the absence of all qualities, which literally was identified with Brahma or the supreme deity, who, although devoid of all the qualities of nature, was simultaneously the source of all nature and pervaded all living and nonliving objects of the world.117In Indian religious cosmology, the concept of *sunya* represents the simultaneous absence and presence of an entity, similar to the use of *sunya* or "zero" in mathematical calculation, which signifies the presence of absence on its own but signifies presence when placed in the decimal system of numeration.118A similar symbol was further developed by the Buddhist conception of *sunyata* in the fifth century B.C., and with the spread of Buddhism, it was transmitted to other east Asian cultures, including China. Joseph Needham has argued that "the "emptiness" of Taoist mysticism, no less than the "void" of Indian philosophy, contributed to the invention of a symbol for *sunya*, i.e. the zero." Nevertheless, he admits of the "probability that the written zero symbol, and the more reliable calculation which it permitted, really originated in the eastern zone of Hindu culture where it met the southern zone of the culture of the Chinese."119

Although the concept of "zero" seems to have been present in the Babylonian culture in the form of an empty space

between numbers, it was

never used in computation, 120and as D. E. Smith has pointed out, the Babylonians did not "create a system of numeration in which zero played any part as it does in the one which we now use."121Similarly, the Mayans also used a symbol for zero associated with place value. However, their place value was inconstant and was neither sexagesimal nor decimal.122So, although the concept of zero was present in a number of other cultures at various points in history, evidence suggests that it was the ancient Indian numeral system, together with the use of zero and the place value system that revolutionized mathematical calculation. It was a development that simultaneously facilitated and was facilitated by the flourishing commerce and trade in that period. Overall these developments, together with the Industrial Revolution contributed significantly to the emergence and consolidation of modern science, a process, which, as Bryan Turner has argued, "presupposed the availability of mathematics which had evolved in Indian and Arabic civilizations."123

Medicine And Surgery in Ancient India: The Case Of Ayurveda

Together with various aspects of science and technology discussed above, a range of medical doctrines and practices developed and flourished in ancient India. Although the medical doctrines of the early ancient period originated from diverse intellectual and sociohistorical traditions, they share some fundamental theoretical and pharmacological assumptions, and can be grouped under the general paradigm of *ayurveda*, which literally means "the science of longevity." This section provides an outline of some of the fundamental assumptions of *ayurveda* together with an account of the social organization of medical practice in ancient India. During the course of this discussion, the significance of the theory and practice of *ayurveda* for the development of pharmacological, botanical, chemical, and anatomical knowledge will also be outlined.

The Medical Doctrines Of Ayurveda

The key texts of *ayurveda*, the *Caraka-Samhita*,124and *Susruta-Samhita* (c. 200 B.C.400 A.D.) are usually represented in the classical Indian tradition as the products of divine origins.125Such a conception of divine origins would imply that *ayurveda* constitutes a complete and closed system of final truth and is therefore not scientific insofar as it is not open to modification. However, historians of science and medicine have pointed out that the notion of the divine character of *ayurveda* is an imposition of religious orthodoxy that developed during the early centuries of the first millennium A.D. This process involved the accumulation and systematization of a diverse body of medical doctrines by "heterodox ascetic intellectuals" during the Vedic and Buddhist era, which was followed by a period when "Hinduism assimilated the storehouse of medical knowledge into its socioreligious intellectual tradition and

by the application of an orthodox veneer rendered it into a brahmanic science." 126This point is of some significance because, the concept of the divine origins of *ayurveda* notwithstanding, the system of medicine practiced in ancient India was partly based on rational empirical observation and was open to revision under different sociohistorical settings. Various schools of practitioners, at different points in history, contributed to the two main texts associated with *ayurveda*, the *Caraka-Samhita* and *Susruta-Samhita*.

These texts, together with some other minor treatises, contain detailed discussions of the relationship of humans to nature, theories of disease, diagnosis, preparation of drugs, and methods of treatment through the deployment of pharmacological and surgical procedures. The *Caraka-Samhita* concerns itself primarily with pharmacology, while the *Susruta-Samhita* concentrates on elaborate descriptions of surgical procedures. Its text describes over 120 surgical instruments.127

The Etiology Of Ayurveda

Central to the etiology of *Ayurvedic* medicine is the concept of three humors*vayu* (gaseous element or wind), *pitta* (fiery element or bile), and *kapha* (liquid element or phlegm), which together comprise the fundamental elements, or *dhatus*, of the human system. Disease is a condition of the body and mind that results from an imbalance of these *dhatus*, and

diagnosis and treatment of disease consist of restoration of the normal proportions of these elements through pharmacological or surgical intervention. The basis of *Ayurvedic* pharmacology lies in differentiating the inherent properties of substances that include: *rasa* (taste), *guna* (quality), *virya* (potency), *vipaka* (assimilability), and *prabhava* (inherent nature or specific action).128The *Susruta-Samhita* divides all drugs into two categories on the basis of the type of action they perform: *samsodhana* (purificatory) and *samsamana* (pacifying). The same text also categorizes surgical intervention into two basic types: the removal of foreign bodies embedded in the system and the treatment of disease not amenable to pharmacological treatment. Surgical treatment is described as proceeding in three stages: *purvakarma* (preparatory measures), *pradhanakarma* (principal measures, or the act of surgery), and *pascatkarma* (postoperative measures). Postoperative measures are particularly emphasized to ensure proper healing. Finally, the following eight major surgical procedures are discussed in detail: *chedana* (excision), *bhedana* (incision), *lakhana* (scraping), *esana* (probing), *vedhana* (puncturing), *aharana* (extraction), *visravana* (draining of fluids), and *sivana* (suturing).129The goal of all these surgical procedures is to restore the normal state of balance of the *dhatus* of the body. Overall, the *Ayurvedic* medical doctrine is informed by a conception of a relationship between humans and nature in which humans represent the microcosm of the larger macrocosm of nature. Or, as conceptualized in the

Caraka-Samhita, "Whatever concretely exists in the world, exists also in man (*purusa*); whatever concretely exists in man, exists also in nature." 130

The Role of Empirical Observation in Ayurveda

One of the significant aspects of the practice of *Ayurvedic* medicine lies in the fact that its practitioners emphasized the importance of direct observation for the accumulation of medical knowledge. So, although the medical system was oriented around certain basic principles like the theory of three kinds of humors, or the balance of *dhatus*, it did not constitute a closed system of thought but emphasized the fruitfulness of direct empirical observation and was amenable to revision as a consequence of these observations. The emphasis in the *Susruta-Samhita* on dissection and direct observation of human anatomy underscores the centrality accorded to empirico-rational procedures for the development of medical knowledge and practice. The initial anatomical knowledge seems to have been acquired indirectly as a consequence of the Vedic sacrificial rites involving the slaughter of horses and cows.131According to the *Susruta-Samhita*,

> The different parts or members of the body as mentioned beforeincluding the skincannot be correctly described by one who is not versed in anatomy. Hence any one desirous of acquiring a thorough knowledge of anatomy should prepare a dead body and carefully observe, by dissecting it, and examine its different parts. For a thorough knowledge can only be acquired by comparing the accounts given in the *shastras* with direct personal observation.132

The text moves on to a detailed description of a particular procedure for observing the anatomical features of the human body. Thus,

> A body selected for this purpose should not be wanting in any of its parts, should not be of a person who has lived up to a hundred years. The body should be left to decompose in the water of a solitary and still pool. After seven days the body would be thoroughly decomposed, when the observer should slowly scrape off the decomposed skin and carefully observe with his own eyes all the various different organs, internal and external, beginning with the skin as described before.133

In another section of the text, the following procedure is recommended:

> Therefore, after having cleansed the corpse, there is to be a complete visual ascertainment of the limbs by the bearer of the knife who desires a definite knowledge [of the body]. For, if one should learn what is visually perceived and what is taught in the textbooks, then both together greatly increase one's understanding [of the human body].134

These extracts underscore the fact that although in the pre-Vedic and Vedic period the practice of medicine was inextricably intertwined with the culture's religious and magical beliefs, it later evolved into a system that incorporated

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direct empirical observation for the development of medical knowledge. Thus an early Vedic text like the *Atharvaveda* consists of medical hymns and charms, and most of the deities mentioned in these charms are either malevolent demons of disease or benevolent plants and their products. 135The medical hymns of the *Atharvaveda* indicate the practice of specialized healing rites involving the recitation of charms and the use of particular plant and animal products as amulets. These special charms together with amulets, or magically potent substances, constituted the healer's "weapons" for engaging in a ritual battle to expel the disease causing demons and for protecting the victims from further attacks.136Overall, the existence of a medical mythology points to a particular Vedic tradition that had the principal function of restoring members of the society to physical and mental health and of maintaining them in this condition through specialized rituals. The practitioners of medicine were not part of the priestly sacrificial tradition but freely borrowed elements from it to accomplish their ends.137

Such practices however, influenced as they were by the larger social and magico-ritual context, succeeded in imparting an empirical dimension to the theory and practice of medicine. In marked contrast to the medical traditions of ancient Egypt and Mesopotamia, the Indian diagnostic system established the cause of affliction by isolating and identifying dominant and recurring symptoms. And it was this technique, "unique to Vedic medicine," which probably marked the beginnings of the strong emphasis on observation and empiricism in the ancient Indian context.138Overall, the development of an empirical and experimental orientation in medicine in ancient India was in marked contrast to the ancient Greek tradition of Galen and Aristotle. Within the framework of Aristotelian scholasticism, the development of an empirical and experimental orientation was not encouraged, and it was not until the sixteenth century that basic observation and experimentation in anatomy had taken place in western Europe.139As Bryan Turner has pointed out, "even in Rembrandt's painting of the anatomy lesson of 1631, which combined the symbols of Protestant spirituality, bourgeois nationalism and observational science, the conventional sign of the anatomical atlas still enjoyed a certain dominance and priority over the naked corpse."140Empirical and observational orientation in medicine in ancient India was threatened by a similar scholasticism, but changing social factors contributed to the further its transformation and further development.

Medical Practitioners and Social Structure: The Social Organization of Medicine in Ancient India

A number of social factors facilitated the gradual transformation of Indian medicine from its predominantly magico-religious orientation to a system based largely on empirical and rational observation. The carriers of medical

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knowledge who combined a magico-religious epistemology with practical techniques of healing in the early Vedic period were outside the general domain of the sacrificial cults but were comparable to the sacrificial priests in their particular sphere of ritual healing and respected for the special skills and knowledge they possessed. 141A specific hymn from the *Rgveda* indicates that in terms of social status, medical practitioners and carriers of this knowledge were placed in the middle of a threefold list of skilled professionals that included carpenters (*taksan*), healers (*bhisaj*), and priests (*brahman*).142Thus, physicians and healers constituted a particular group of "professionals" who combined the craftsmanship of a carpenter with the intellectual acumen of the priest. Like the learned priests, the healers commanded esoteric knowledge, and like the uneducated but skilled carpenters, they "repaired" the injured or broken human body. Within the social hierarchy of the early Vedic period, they were respected and even praised in the *Rgvedic* hymns for the healing services they performed. However they were never considered on a par with the ritualists of the sacrificial cults.143

In the subsequent late Vedic period, with the consolidation of the powers of the priestly caste of Brahmans, the practice of medicine and medical knowledge came to be denigrated. One of the consequences of this social transformation was the gradual decline in the social status of healers. In the transformed social structure where Brahmans acquired dominance, physicians came to be considered impure agents of pollution. More specifically, Brahmans themselves were prohibited from practicing the art and craft of healing. Specific texts from this period, like the late *Samhitas* and the *Satapatha Brahmana* provide evidence for the fact that physicians as a category were denigrated and considered impure because of their constant bodily contact with people of various status in the course of performing cures. However,

individual healers could practice medicine in the Brhamanic setting provided they underwent a purification ceremony. The later law books recite passages from the Laws of Manu, stating that physicians must be avoided at sacrifices and that the food given by them was impure and should not be consumed. Of course such ideological strictures did not stamp out the practice of medicine completely.

One of the consequences of these social changes was the exclusion of medical practitioners from the Brahmanic social structure. The healers who were excluded from mainstream society organized themselves as sects of "roving physicians" (*caranavaidya*), and earned their livelihood by administering cures in the countryside. These wandering physicians, shunned by the hierarchy of mainstream society, came in contact with groups of heterodox ascetics, or *sramanas*, who were more receptive to the healing arts as well as to a more observational orientation. Both groups were indifferent or even antagonistic towards the orthodox scholastic tradition, and further development of medical knowledge and the healing arts found a receptive home amongst the sects of *sramanas*, which included Buddhists, Jains, and

Ajivakas. 144In due course, the healers became indistinguishable from the other *sramanas*, and the use of empirical procedures and direct anatomical observational techniques contributed to a vast storehouse of medical knowledge, which supplied the Indian medical tradition with the precepts and practices of what later came to be known as *Ayurveda*.145

Healing and Education in Buddhist Monasteries

Further growth and refinement of medical knowledge and practice were facilitated by Buddhist monks who contributed to the development of techniques of empirical observation. Among the Buddhist monks, medical knowledge became an integral part of the religious doctrine and monastic discipline, and the Buddhist *sangha*, or monastic community, eventually emerged as the primary institution and vehicle for the preservation, development, and transmission of this knowledge. By the time of the reign of emperor Asoka (c. 269232 B.C.), the Buddhist monasteries had developed into medical establishments or hospices. The second rock edict of Asoka proclaims that throughout his empire, medical treatment is to be provided to both humans and animals, and medicinal herbs and roots are to be imported and planted wherever they are not found. This was a period of growth for Buddhism and for the spread of its monasteries in northeastern India.146Textual sources and other inscriptions attest to the institutional support for the practice of medicine in this period. A Pali text refers to a "hall of the sick" (*gilansasala*); an inscription from Nagarjunikonda, a famous Buddhist monastery, dating from the third century A.D. mentions a health house attached to the main structure; the Chinese Buddhist pilgrim Fa-hsien who visited India in the fifth century A.D. describes the established houses at the city of Pataliputra for dispensing medicine to the poor and destitute, and such a structure may have been the *arogyavihara* (health house) of the Buddhist monastery in the same city; finally at a Buddhist site in Nepal, an inscription dated to 604 A.D. refers to a donation of land by a king for a health house (*arogyasala*).147Overall, the canonical literature of Buddhism provides ample evidence that medicine and healing were integral parts of Buddhist monasticism from its inception.148The medical section of the monastic code contains many accounts of the treatment of monks, and these case histories provide a good glimpse of the medical practice current in the Buddhist monasteries in the ancient period.149

With the passage of time, some of the larger Buddhist monasteries emerged as centers for imparting medical education. Taxila, one of the more established educational institutions of ancient India was imparting medical studies as well as education in the arts and the sciences in early first century A.D. During this period Buddhism also flourished at Taxila and archaeological excavations indicate that Buddhist monastic establishments existed there from the early Kusana period until its sacking by the Huns in the fifth century A.D.150

By the mid-sixth century A.D., toward the end of the Gupta dynasty, a number of monastic educational institutions were operating in northeastern India. The most well known of these, the monastery at Nalanda has been described by the Chinese Buddhist traveler Yuan Chwang, or Hsuan-Tsuang, who was in India from 629645 A.D., as a center of education, attracting students from distant areas of the region. They came to study logic (*hetuvidya*) and medicine (*cikitsavidya*) that formed part of the five sciences, or "knowledges" (*vidya*), of the traditional curriculum. 151Another Chinese Buddhist traveler, I-Tsing, who visited India in the latter half of the seventh century A.D. also described the

study of the five sciences, including medicine. According to I-Tsing, the practice and teaching of medicine consisted of eight sections: "The first treats of all kinds of sores; the second, acupuncture for any disease above the neck; the third, of disease of the body; the fourth of demonic disease; the fifth, of Agada medicine [i.e. antidotes]; the sixth, of the diseases of children; the seventh, of means of lengthening one's life; the eighth, of methods of invigorating the legs and body."152By the middle of the seventh century A.D., medical knowledge was codified as a system and constituted an integral part of the curriculum of the five sciences taught at Buddhist monastic educational establishments. Around the tenth century A.D., medicine was integrated into religious life, leading to the establishment of institutions for healing as well as medical education in a number of places. A Tamil inscription (1069 A.D.) from the Visnu temple at Tirumukkudal in Tamil Nadu provides detailed information about a hospital attached to it. The inscription provides details such as the numbers of beds, the funds for a staff of nurses, surgeons, etc.153A copperplate inscription (930 A.D.) from southeastern Bengal refers to a grant from King Sricandra for the patronage of physicians attached to each of the two Brahmanic religious institutions, or *mathas*.154With the dramatic decline of Buddhism in India in the thirteenth century, the preexisting Hindu religious institutions developed further and provided medical treatment as well as education and apprenticeship.

The above account has focused on the diverse social origins of the doctrine and practice of *Ayurveda* in ancient India. To recapitulate, the medical doctrines of ancient India incorporating a distinct etiology and based on a magico-religious cosmology, emerged in the early Vedic period. After a period of development, the emergence and consolidation of the Brahmanical social structure marginalized the practitioners of this system of medicine who were considered to be ritually polluting and impure. The decline in the ritual status of the healers forced them to traverse the countryside in roving bands where they practised their healing arts and came in contact with groups of heterodox Buddhist and Jain ascetics, or *sramanas*. Over a period of time the healers were absorbed into the various sects of the heterodox ascetics who imparted an empirico-rational dimension to the medical knowledge acquired from the healers and helped systematize, preserve and propagate *Ayurveda*. With the ascendancy of Buddhism in the first few centuries of the common era,

Buddhist monasteries institutionalized the practice and teaching of *Ayurveda*. With the decline of Buddhism in the thirteenth century A.D., the Hindu monastic institutions inherited a transformed system of medicine, and a number of infirmaries and hospitals were established on the Buddhist pattern. Over a period of time, these doctrines were codified as the *Caraka-Samhita* and *Susruta-Samhita*. Overall, the system of *Ayurvedic* medicine owes its origins to a diverse range of social and religious factors, and Buddhist ascetism and religious doctrines played a significant role in the development of an empirically based medical epistemology.

Ayurveda and the Development of Botanical, Zoological, and Chemical Knowledge

The growth of medical knowledge also stimulated the development of a number of auxiliary systems of knowledge, which might be labeled as botany, zoology, and chemistry in the modern period. The concern with the preparation of various kinds of medication led to the accumulation of knowledge of the therapeutic properties of a wide range of plants and animals and to specific schemes of classification or taxonomy, which can be found in some of the *Ayurvedic* treatises.

The *Susruta-Samhita* contains a catalogue of a 168 different types of "meats" classified on the basis of the effect their consumption has on the designated humor, i.e., wind, bile, or phlegm. 155Although the main purpose of this exercise was the elucidation of the pharmaceutical and therapeutic properties of these "meats," or animals and birds, it led to a fairly comprehensive and rigorous taxonomical scheme of the animal kingdom. As Francis Zimmermann has argued, the number of species actually utilized in the *materia medica* of this period would have been just a fraction of the number actually mentioned in the catalogue of the *Susruta-Samhita*, and this text represents "a kind of 'zoology' a corpus of knowledge about the fauna, knowledge not set out as such but slipped into the mould of discourse intended for the use of medical practitioners."156In the first instance, the animals are classified according to two polar divisions: those that live on the dry lands (*jangala*) and those that live in wet habitats (*anupa*). This primary division is further subdivided according to biogeographical criteria. Overall, it is a comprehensive taxonomic catalogue of the animal kingdom, complete except for the insects, which are discussed separately in texts concerned with the effect of poisons and venoms.157

Similarly, the practice of *Ayurveda* stimulated the accumulation and systematization of botanical knowledge, which was

recorded in the "dictionaries" or pharmacopoeias (*nighantus*). As Zimmermann158has pointed out, the role of these dictionaries in the codification and transmission of taxonomical knowledge cannot be overemphasized. These "dictionaries," some of which were recorded as early as the fourth century A.D., provide a comprehensive list of

plants and herbs classified on the basis of their pharmacological properties. Analysis of the systems of taxonomical classification utilized in these compediums of plants is still in progress, and Kenneth Zysk 159has provided an exhaustive list of 130 plants that were identified, classified, and recorded in these pharmacopoeias. Although circumscribed by pharmacological and medical concerns, the compilation of these texts, which also contain elaborate classifications of different types of leaves and fruits, led to the accumulation and transmission of considerable botanical knowledge in ancient India.160

Finally, the preparation of medicines and attempts to understand the physiology of the process of digestion, which constituted an integral part of the *Ayurvedic* system of medicine, led to the development of knowledge of certain chemical reactions, which have been recorded in a number of early texts. Both the *Caraka-Samhita* and the *Susruta-Samhita* refer to chemical preparations for use as medicine, and the latter text contains detailed instructions for the preparation of chemical compounds and salts that would be recognizable as "alkalis" in the terminology of contemporary chemistry.161The same text also contains explicit instructions for the preparation of alkali carbonates and caustic alkali as well as for the neutralization of alkalis by acids. The textual evidence is corroborated by archaeological excavations that have unearthed mortars and pestles at an infirmary attached to a monastery at Sarnath near the present-day city of Varanasi.162Parenthetically it might be mentioned that the prominent French chemist M. Berthelot's surprise at the accuracy of the procedures described for the preparation of alkalis led him to suggest that these passages were inserted into the ancient texts after the Indians came into contact with European chemistry.163In any case, the preparation of medicines within the *Ayurvedic* tradition of ancient India evoked interest in the chemical processes and reactions that constituted the basis of incipient chemistry in ancient India.

The above discussion has focused mainly on the ancient and the early medieval period. The next chapter provides an account of science and technology in medieval India up to the onset of British colonial rule. Although the discussion in both chapters is predominantly descriptive in nature, the concluding section of the next chapter provides some theoretical generalizations about the relationship among scientific knowledge, technology, and social structure.

Notes

1. Charles Grant quoted in Syed Mahmood, 1895: 1113.

2. James Mill, vol. 2, 1840: 10001, 150.

3. Thomas Babington Macaulay, "Minutes of 2 February 1835," in H. Sharpe, ed., 1920.

4. Macaulay in Sharpe, ed., 1920.

5. Grant in Mahmood, 1895: 1113.

6. Javed Majeed, 1992: 192.

7. Cited in Majeed, 1992: 193.

8. Eric Wolf, 1982.

9. Michael Adas, 1989.

10. Alfred Chatterton, quoted in Shiv Visvanathan, 1985: 44.

11. William Jones, 1799c: 430.

12. H. T. Prinsep in Sharpe, ed., 1920: 126.

13. Adas, 1989: 107.

14. Har Bilas Sarda, 1906: 364.

15. *Ibid.*: 365.

16. For a report on the assumptions and proceedings of the Congress, please see Venugopal S. Rao, 1994.

17. P. N. Bose (1885), quoted in R. C. Prasad, 1938: xiixiii.

18. Bruno Latour, 1987: 174.

19. The term "India," although a modern concept, is used loosely to denote the cultural and civilizational complex of south Asia. The use of the term is not to be confused with the conception of a timeless, clearly demarcated, and constituted nation as resurrected in the current Hindutva discourse in India. For a recent discussion of the problems associated with demarcating regions and histories into discrete bounded entities, please see David Ludden, 1994.

20. Bridget Allchin and Raymond Allchin, 1982: 131. In this section, unless otherwise indicated, I rely mainly on Allchin and Allchin for reconstructing the social structure of the Indus Valley civilization. This work constitutes a synthesis of a number of key archaeological studies and represents an authoritative account of the accumulated archaeological knowledge of the area. Other discussions of the Indus Valley civilization include G. L. Possehl, ed., 1979; 1982; D. D. Kosambi, 1965.

21. Allchin and Allchin, 1982: 125. Further discussion of the evidence of trade in this early period can be found in Asko Parpola, 1986; S. R. Rao, 1963.

22. Allchin and Allchin, 1982: 165.

23. *Ibid.*, 148.

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24. *Ibid.*, 158.

25. *Ibid.*, 162.

26. *Ibid.*, 192.

27. *Ibid.*, 165.

28. *Ibid.*, 22324.

29. *Ibid.*, 173.

30. *Ibid.*, 176.

31. *Ibid.*, 19192. Further details of the cultivation of cotton in the ancient period can be found in D. Schlingoff, 1974; L. Gopal, 1961; Romila Thapar, 1959.

32. Allchin and Allchin, 1982: 18889.

33. *Ibid.*, 28081.

34. *Ibid.*, 189.

35. Detailed studies of these systems of weights and measures can be found in V. B. Mainkar, 1984; B. B. Vij, 1984.

36. A. I. Volodarsky, 1974.

37. Allchin and Allchin, 1982: 185.

38. Volodarsky, 1974: 357.

39. Vij, 1984: 154.

40. Parpola, 1979: 401.

41. Parpola, 1976: 24452; 1986: 413; 1979.

42. Parpola, 1986: 413.

43. Parpola, 1975: 19495.

44. Joseph Needham, 1959: 246.

45. Needham, 1981: 91.

46. Parpola, 1975: 195.

47. Parpola, 1976: 251.

48. K. V. Sarma, 1985: 16.

49. Please see S. M. Ashfaque, 1977; 1989; A. K. Bag, 1985; Parpola's interpretation of the fish sign is accepted and used as a basis for further investigation

by Y. V. Knorozov et al., 1979, and I. Mahadevan, 1970. However, such attempts at deciphering the Indus script have been challenged by B. B. Lal, 1973. It must be noted that the Scandinavian scholars followed an earlier lead offered by Henry Heras, 1953.

50. In this section I rely heavily on S. N. Sen and A. K. Bag, 1983; G. Thibaut, 1984 [1875]; B. Datta, 1932.

51. G. G. Joseph, 1991: 228; However, D. P. Chattopadhyaya, 1986: 123 dates the texts between 800 and 250 B.C.

52. Joseph, 1991: 225.

53. *Ibid.*, 226.

54. Thibaut in B. D. Chattopadhyaya, vol. 2, 1982: 449.

55. A good discussion of the ritual origins of geometry can also be found in Frits Staal, 1982.

56. Further details of the specific calculations involved in the construction of this particular form of altar can be found in B. D. Chattopadhyaya, vol. 2, 1982: 45663.

57. Thibaut in B. D. Chattopadhyaya, 1982: 422.

58. *Ibid.*, 422.

59. Joseph, 1991: 23033.

60. *Ibid.*, 233.

61. *Ibid.*, 234; T. A. Saraswathi, 1969: 6061.

62. Joseph, 1991: 23436. A detailed discussion of these calculations can also be found in Saraswathi, 1969: 5978.

63. Joseph, 1991: 228.

64. *Ibid.*, 226.

65. T. A. Saraswathi Amma, 1979. Saraswathi Amma provides the most detailed analysis of the development of mathematics in ancient India.

66. G. Sundaramoorthy, 1974: 10006.

67. K. S. Shukla, 1987: 9.

68. R. Sarkar, 1987: 9.

69. Shukla, 1987: 10.

70. *Ibid.*

71. David Pingree, 1981.

72. K. V. Sarma, 1985: 4.

73. *Ibid.*, 5.

74. The best detailed account of the elements of astronomical thinking during this period in India can be found in Sen and Shukla, eds., 1985 and G. Swarup et al., 1987.

75. A. K. Chakravarty, 1987: 24.

76. Joseph, 1991: 264.

77. Ibid.

78. Shukla, 1987: 14.

79. P. Gangooly and P. Sengupta, eds., 1935.

80. Joseph, 1991: 265.

81. J. J. Winter, 1975: 15253.

82. Walter Eugene Clark, 1962: 366.

83. Needham, 1969: 44.

84. S. R. Sarma, 1987: 6374.

85. Aryabhata, 1874; Clark, 1930.

86. Joseph, 1991: 266.

87. Clark, 1962: 350.

88. Joseph, 1991: 26667.

89. Ibid., 267. Details of the mathematics of this period can also be found in Henry T. Colebrooke, 1817.

90. S. R. Sarma, 1987: 63.

91. For an excellent and exhaustive account of the instruments and methods of use as recommended by Brahmagupta,

see S. R. Sarma, 1987.

92. S. R. Sarma, 1987: 72.

93. L. Wilkinson, 1974; Lynn White Jr., 1962: 130.

94. Wilkinson, 1974: 22728; White, 1962: 131.

95. White, 1960: 522.

96. White, 1962: 12930.

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97. *Ibid.*, 130.

98. *Ibid.*, 131.

99. White, 1960: 52223.

100. White, 1962: 131.

101. *Ibid.*, 134.

102. Joseph, 1991: 26768.

103. *Ibid.*, 26869.

104. Clark, 1962: 365.

105. Joseph, 1991: 269.

106. Colebrooke, 1817.

107. J. J. Winter, 1975: 156. See also J. J. Winter (1952) for a detailed account of Bhaskara's contribution to the theory of numbers.

108. J. J. Winter, 1975: 157.

109. Joseph, 1991: 270.

110. *Ibid.*, 298.

111. Clark, 1962: 361. See also G. R. Kaye (1927). None of the historians of science agree with Kaye's dating of the manuscripts to the twelfth century A.D.

112. Clark, 1962: 35859.

113. *Ibid.*, 359.

114. See D. E. Smith and L. C. Karpinski, 1911; F. Cajori, 1919, Clark, 1929; Dirk Jan Struik, 1967; Brian Rotman, 1987; White, 1962.

115. Cited in Clark, 1962: 360.

116. Struik, 1967: 41.

117. R. N. Mukherjee, 1977: 22431.

118. R. N. Mukherjee, 1977: 226.

119. Needham, 1954: 1112.

120. *Ibid.*, 16.

121. D. E. Smith, vol. 2, 1958: 69.

122. Needham, 1954: 16.

123. Bryan Turner, 1987: 21.

124. P. M. Mehta, ed. and trans., 1949.

125. Kenneth G. Zysk, 1991: 4; G. Jan Meulenbeld, 1987: 2. A detailed but contested account of *Ayuveda* can be found in J. Filliozat, 1964. See Debiprasad Chattopadhyaya, 1977 for a critical account of Filliozat's interpretations.

126. Zysk, 1991: 6. The same point is also emphasized in Meulenbeld, 1987: 2.

127. Clark, 1962: 354. A detailed account of surgical instruments and procedures is provided by Mira Roy, 1986: 17072. Zysk, 1991 offers a detailed account of specific case studies of treatment of diseases, especially in chapters five and six.

128. Roy, 1986: 168; Meulenbeld, 1987: 5 list only four: taste (*rasa*), postdigestive taste (*vipaka*), potency (*virya*), and specific action (*prabhava*).

129. Roy, 1986: 170. See also Debiprasad Chattopadhyaya, 1977: 23, 9697, 11920 for a detailed account.

130. P. M. Mehta, ed., vol. 4, 1949: 4.13. Cited in Debiprasad Chattopadhyaya, 1977: 60.

131. Zysk, 1986: 687705.

132. *Susruta-Samhita*, vol. 3, 5.5960. Cited in Debiprasad Chattopadhyaya, 1977: 94.

133. *Susruta-Samhita*, vol. 3, 5.61. Cited in Debiprasad Chattopadhyaya, 1977: 95.

134. *Susruta-Samhita*, cited in Zysk, 1991: 35.

135. Zysk, 1991: 17.

136. *Ibid.*, 16.

137. *Ibid.*, 17.

138. *Ibid.*, 15.

139. Turner, 1987: 89.

140. *Ibid.*, 9. See also Turner, 1990: 118.

141. In this section, I rely Zysk, 1991, chapters 2 and 3.

142. Zysk, 1991: 21.

143. *Ibid.*, 2122.

144. *Ibid.*, 2627.

145. In this discussion, I rely extensively on Zysk, 1991.

146. Zysk, 1991: 44.

147. *Ibid.*, 4445.

148. *Ibid.*, 50. See also chapter 5 for further details of the discussion of medicine and healing in the Buddhist canonical literature.

149. For a full account, see Zysk, 1991, chapter 6 and appendix 1.

150. Zysk, 1991: 47.

151. *Ibid*. See also Thomas Watters, vol. 1, 1961: 15460, 16469, for further details of the educational establishment at Nalanda and other regions of ancient India.

152. I-Tsing, 1982: 12728, cited in Zysk, 1991: 48.

153. Zysk, 1991: 4546.

154. *Ibid.*, 45. Details of other evidence from inscriptions may be found on pp. 4546 of the same text.

155. Francis Zimmermann, 1987: 98.

156. *Ibid*. For this section, I rely on chapter 4.

157. A complete list of the classificatory catalogue can be found in Zimmermann, 1987: 10311, 242249.

158. Zimmermann, 1987: 99.

159. Zysk, 1991: 12832. Other discussions on this topic include Rahul Peter Das, 1987: 1924; U. C. Dutt and George King, 1922.

160. For a recent account of early classificatory principles in a number of societies, please see Brent Berlin, 1992.

161. P. Ray, 1986: 137.

162. Zysk, 1991: 45.

163. Joseph, 1991: 216.

3
Science, Technology, And Society In Medieval India

These Heathen phisitions doe not onely cure their owne nations and countrimen but the Portingales also, for the Viceroy himself, the Archbishop, and all the Monkes and Friers doe put more trust in them then in their own countrimen, whereby they get great money, and are much honoured and esteemed.
John Huyghen van Lichschoten, c. 1585 1

On physic they have a great number of small books. Their practice differs essentially from ours. Whether these modes of treatment be judicious, I leave to our learned physicians to decide. I shall only remark that they are successful in Hindoustan.
Francois Bernier, 16602

They practice with great success the operation of depressing the chrystalline lens when become opake and from time immemorial they cut for the stone at the same place which they do now in Europe.

Dr. Helenus Scott 17923

Inoculation is performed in Indostan by a particular tribe of Bramins, are delegated annually for this service from the different Colleges. They lay it down as a principle that the immediate cause of the small pox exists in the mortal part of every human and animal form; that the mediate (or second) acting cause, which stirs up the first, and throws it into a state of fermentation, is multitudes of imperceptible animalculae floating in the atmosphere.
Dr. J. Z. Holwell, 1767 4

From what I have seen of Indian iron, I consider the worst I have ever seen to be as good as the best English iron. There is hardly any of the above tests, which the good native iron of Southern India will not bear. [It] has stood drawing out under the hammer into a fine nail rod not 1/10th inch thick, without splitting. An inch bar of good iron thus treated will bear a dozen blows of a heavy sledge hammer before it will break.
J. Campbell, 18425

The fire is urged by several bellows of a construction peculiar to the country; the wood is charred, the iron fused, and at the same time converted into steel. The chief peculiarity in this neat and ingenious method of steel-making, consists in the wood not being previously charred. The experience of twenty-five years fully confirms the sanguine opinion then given, Wootz [Indian steel], when properly treated, proving vastly superior to the best cast-steel of Europe. [It] is invaluable for surgical instruments, where mediocrity is not, at least.
J. Stodart, 18186

The legacy of the dominant colonial image of a stagnant and static society notwithstanding, medieval India was characterized by a high degree of economic and manufacturing enterprise. Sixteenth- and seventeenth-century India represented a functioning money economy, accompanied by extensive employment in the craft sector, and the production of a large volume of manufactured goods for the internal and overseas market.7Without a fairly vibrant

economy and a robust manufacturing sector, the extensive network of maritime trade in cotton textiles, iron, and steel, ranging from Southeast Asia, west Asia and Africa to western Europe would not have been possible. 8The manufacture of a wide variety of cotton fabrics was especially well developed in precolonial India. Evidence from the records of the European trading companies in the seventeenth and eighteenth centuries suggests that in the trade of this commodity, India enjoyed a virtual monopoly in the export markets. Although hand weaving of cotton textiles was common in a number of countries having access to local supplies of cotton staple, the finer luxury products that dominated the international market were almost entirely supplied by India.9Prior to the development of machine spinning in Britain in the second half of the eighteenth century, the Indian subcontinent was the largest producer of cotton textiles, an activity that presupposes a degree of technical skill and technological innovation. The following section provides an account and evaluation of the technology and social organization of the manufacture of cotton textilea commodity that not only enabled medieval India to attain a preeminent position in the precolonial era, but also constituted one of the factors that eventually precipitated the Industrial Revolution in Britain.10

The Social Organization and Technology of Cotton Manufacture in Medieval India

Although this section focuses on the medieval period, a very brief discussion of the production of cotton textiles in the ancient period will help trace certain patterns of continuity through history. Whereas concrete archaeological evidence for the production of cotton textile in India is available from the earliest phase of the Indus Valley civilization, there is little information available about the actual mode of cultivation, technology, or the social organization of its production in this period. The earliest descriptions of the production of cotton textiles come from literary references. Nearchus, Alexander's admiral, recorded that "the dress worn by the Indians is made of cotton produced on trees"11and in Herodotus VI, there is an account of "trees which grow wild, the fruit of which is a wool exceeding in beauty and goodness that of sheep. The Indians make their clothes of this tree wool".12Similarly Theophrastus describes the "trees from which the Indians make cloth have a leaf like that of black mulberry. They set them in plains arranged in rows so as to look like vines at a

distance". Arrian's *Indica* provides an account of "trees bearing, as it were, bunches of wool. The natives made linen garments of it, wearing a shirt which reached to the middle of the leg, a sheet folded around the shoulders, and turban rolled around the head, and the linen made by them from this substance was fine, and whiter than any other."13

Kautilya, whose work was described by Max Weber as representing "a really radical Machiavellianism," 14 provides an account that offers some insight into the social organization of the manufacture of cotton textiles. In his *Arthsastra*, composed at the height of the Mauryan empire in the third century B.C., Kautilya refers to the "superintendent of yarns (*sutradhyaksa*)" who should "get yarn spun out of wool, bark-fibres, cotton, silk-cotton, hemp and flax, through widows, crippled women, maidens, women who have left their homes and women paying off their fine by personal labor, through mothers of courtesans, through old female slaves of the king and through female slaves of temples whose service of the gods has ceased."15While the spinning of the yarn was undertaken by women on the margins of society who worked under conditions of coercion, the actual weaving of the cotton threads into textiles was accomplished by male artisans who presumably worked for wages. Thus, according to Kautilya, the "superintendent of yarns" should "cause work to be carried out by artisans producing goods with an agreement as to the amount of work, time and wage, and should maintain close contact with them."16The gendered division of labor in the manufacture of cotton in the ancient period is corroborated by another text, the *Divyavadana*. According to a passage in the text, "[The wife of the Brahmin] went to the market and bought cotton. Having prepared it, she spun a fine thread and caused a stuff of the value of one thousand coins to be woven by a skilled weaver."17A painting from the Ajanta Caves provides pictorial confirmation of women spinning cotton yarn in the ancient period.18Evidence of historical continuity in the pattern of this gendered division of labor in the production of cotton comes from a twelfth-century text, which describes the work of "a woman making loose the yarn etc. by batting; separating, ginning the cotton. She spins, she gins, she looses, she bats."19Further evidence of a similar division of labor comes from these words of resentment against Razia Sultan, a woman who ruled a region of India from 12361240 A.D.: "That woman alone is good who works all the time with the *charkha* (spinning wheel); for a seat of honour would deprive her of her reason. Let cotton be the woman's companion; grief her wine-cup; and the twang of the spindle will serve well for her minstrel."20This gendered division of labor seems to have continued throughout the medieval period up to the eighteenth century.21

The manufacture of cotton textiles involved a number of distinct steps, each entailing a high degree of specialized skill and expertise. The highly specialized nature of skills required for each phase led to an elaborate division of labor, and different groups of specialized craftspeople, sometimes located in different geographical areas, contributed to the transformation of raw cotton staple into textile. A discussion of these various steps will help elucidate the social organization as well as the empirical knowledge, technical skills, and technology involved in the production of cotton textiles in medieval India.

The manufacture of cotton textiles entailed four basic steps: preparation of yarn for spinning, spinning, weaving, and, depending on the type of textile

being produced, bleaching, dyeing, or printing. The very first phase, the preparation of yarn for spinning, consisted of a number of interrelated steps like cleaning, ginning, batting, and twisting, which involved the use of certain mechanical devices. The initial cleaning was carried out mainly by women who would pick out dirty and immature cotton seeds and remove minute vegetable matter from the cotton. The ginning process involved the separation of the cotton from the seeds, and this was accomplished by the use of a mechanical device known as the *charkhi*, or the cotton gin, or, more technically, the "wooden worm-worked roller." 22This machine consisted of two cylindrical rollers placed on top of each other, with a handle attached to the upper roller. While the handle was turned by a woman, the cotton was inserted through the revolving rollers, which would let the fibres pass through to the other end and let the seeds too large for passage fall to the ground. In one region between the rivers Indus and Jhelum, the cotton gin was driven by water power, but this innovation was localized and did not spread to other parts of the country.23The rough fibre collected by this process of ginning now had to be "batted" or "carded" in order to loosen the texture and cleanse it of any dust or dirt. This was accomplished by means of a bow-like instrument (*kaman, dhunaki*), the vibrating string of which would open the knots of cotton and loosen it up. The earliest literary evidence for the use of the bow for carding comes from the

second century A.D. from south India,24although it must have been in use from a much earlier period. According to Joseph Needham, the technology for cotton ginning as well as the bow string originated in India.25In some places the older method of simply beating the cotton with sticks was employed. After ginning, the pile of cotton was twisted manually into small rolls called *pini*, which were then ready to be spun into cotton threads.

The next step was spinning the twisted rolls into threads, and prior to the introduction of the spinning wheel, whorls and spindle (*takla* in Hindi or *duk* in Persian) were employed. Although historians like R. J. Forbes26had earlier believed that the spinning wheel had originated in India, it is now clear that there exists no evidence for its use in India prior to the early fourteenth century A.D.27It is likely that the device was introduced in India sometime in the early thirteenth century, even though it was not adopted until much later. One possible sociological factor for its lack of popularity could be the fact that it was a labor-saving device that increased the quantity of thread being spun but did little to improve quality. As a consequence, it was generally employed for the coarser cotton fabrics, and the fine yarn needed for the famous Dacca muslin could only be spun by hand-rotated spindles and whorls. Thus while the use of a spinning wheel brought about a sixfold increase in productivity, it did not promise any substantial improvement in the quality of the fabrics being manufactured and was not adopted as long as there was a market for the finer and more expensive qualities of muslin. A report by John Taylor, an East India Company official, indicates that even as late as the second half of the

eighteenth century, the spinning wheel, although mechanically superior to the whorls and the spindles, was not adopted by the Dacca weavers:

> Thread for coarse assortments is spun by a wheel, for fine by a Spindle. Thread is made at all the *aurangs* [weaving centers], but the greatest quantity, and with few exceptions the best, is spun at Junglebarry Bazetpore; the fabrics from the greatest skill with which the thread is prepared, possess a peculiar softness. The heat of the climate will not admit of Thread of that quality being spun but at particular hours, usually from half an hour after day light, till nine or ten in the morning and from three or four in the afternoon till half an hour before sun set. 28

Besides underscoring the significance of manual control for the quality and excellence of the fabrics, Taylor's report provides clues for understanding some of the sociological factors underlying the adoption or rejection of technical innovations. The threads for Dacca muslin continued to be spun with needle-like bamboo rotated on pieces of hollow shells long after the spinning wheel was adopted for spinning other coarser fabrics.29

Depending on the kind of fabric being produced, the actual weaving involved the use of at least two different kinds of looms. The simplest of these, the "horizontal loom" was most likely in use during the Vedic period, as a verse from the *Atharvaveda*30makes evident. The first inscriptional evidence for it can be traced to the twelfth century. The horizontal loomalso known as the "Indian treadle loom" due to the use of foot treadles to control the shedding mechanismwas generally used for weaving either plain or patterned fabrics that did not require more than two overhead harnesses to control the pattern.31The second type, the "draw-loom," or the patterned loom, invented in China, was more complex and required more than one person to operate. It was used for weaving fabrics with intricate designs and patterns. The presence of the draw-loom in India has been documented from the eleventh century onwards, and its use involved a process by which certain cords were attached to the wooden frame on top of the loom, and patterns were produced when an assistant pulled the cords in the correct sequence, while the weaver threw the shuttle through the resultant sheds.32Although the draw-loom facilitated the weaving of patterned fabrics, it was not adopted all over India. Thus as late as the nineteenth century, the Dacca weavers were producing intricately patterned cloth by means of the ordinary horizontal or treadle loom.33As opposed to the cleaning and spinning of the cotton fibres, which was accomplished mainly by women, weaving was exclusively done by men and was restricted to particular weaver caste groups like the *kori* and the *julahas*.

The final step in the production process was bleaching, and depending on the type of fabric being manufactured, dyeing or printing. The dyeing techniques were highly developed and specialized, and the process was based on practical knowledge of the chemical properties of the various kinds of dyes

employed. These vegetable-based dyes were produced from a number of sources like the indigo plant (*nil*), red safflower (*kusumba*), madder (*manjishta*), lac (*laksha*), and barks of a number of trees. 34The techniques of dyeing were highly evolved and the elaborately painted Indian chintzes that flooded the British markets were produced by the application of as many as twelve separate dye transfer processes to the cloth.35The elaborate patterns were dyed or painted on the fabrics through the application of "resists" to confine colors to the patterns. "Mordants" were then used to fix the colors and render the fabric washable.36Calico printing, or the printing of patterns through the use of blocks, was well developed by the twelfth century. By the seventeenth century, medieval India had become the home par excellence of multicolored calicoes, which flooded the international markets. The tie and dye method was also popular, especially in Gujarat and north Coromandel. After dyeing, the final process of finishing involved the application of a number of caustic agents and chemicals.37The French traveler Jean Baptiste Tavernier who visited India in 1676 observed some aspects of the finishing process and recorded that "the Indians have a way to dip some of these Calicuts [Calicoes] in a certain water that makes them look like watered-chamlets, which adds also to the price. The Calicuts are never so white as they should be, till they are dipped in lemon-water."38The process of dyeing and finishing represented the final step in the production of textiles, and was accomplished by a separate group or caste of highly skilled craftspeople who were quite distinct from the weavers.

As should be evident from the above discussion, the manufacture of cotton fabrics consisted of a number of discrete stages, each involving a degree of technical expertise. This division of labor was not just confined to the technical sphere but had significant consequences for the social organization of the cotton industry and society at large. Unlike most craftspeople who could perform all the different stages of the production, and were at times forced to offer their services to the local princes or rulers, the textile industry required the combined skills of several separate groups of craftspeople. This meant that it was the traders who assumed control over the artisans due to their greater experience of the market. The traders would usually buy the unfinished woven cloth from the weavers and arrange to have it finished or bleached and printed by another group of craftspeople who were sometimes located in a distant region. As Jean Baptiste Tavernier observed, "the Bastaes or Calicuts [Calicos] painted red, blue and black, are carried white to Agra, and Ahmadabat, in regard to those cities are nearest to the places where the indigo is made that is used in colouring."39The overall consequence of this division of labor was the fact that the structure of markets and the patterns of consumer demand had a significant impact on the production of textiles. The cotton textile industry was organized around a system of "commercial advantages," which was different from the putting-out system. Under the traditional contractual system, the merchants

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always advanced cash sums but not raw materials to the weavers. It was the link between the local weavers and the big merchants, who had greater awareness and knowledge of market conditions, that enabled locally produced textiles to be sold in distant markets. The production of textiles in medieval India was essentially geared towards the wholesale trade and constituted one of the factors responsible for the subjection of an industrial craft to commercial capital. 40

Evaluating The Technology Of Cotton Manufacture

Nineteenth-century accounts of British India, while expressing admiration for the quality of Indian textiles were unanimously negative in their evaluation of the technology utilized in its manufacture. Typical of this kind of response is Edward Baines's comment that "it cannot but seem astonishing, that in a department of industry, where the raw material has been so grossly neglected, where the machinery is so rude, and where there is so little division of labour, the results should be fabrics of the most exquisite delicacy and beauty, unrivalled by the products of any other nation, even those best skilled in the mechanic arts."41While it was usual at that time to attribute most of the perceived shortcomings to the ubiquitous caste system, Baines pointed out that "the hereditary practice, by particular casts [sic], classes, and families [as] causes, with very little aid from science, and in an almost barbarous stage of the mechanical arts, that India owes her long supremacy in the manufacture of cotton."42

Echoing Baines's views, James Mill, while accepting that "the manufacture of no modern nation can, in delicacy and fineness, vie with the textures of Hindustan," characterized the weaver's loom as "coarse and ill-fashioned little else than a few sticks or pieces of wood, nearly in the state in which nature produced them, connected by the rudest contrivances to a degree hardly less surprising than the fineness of the commodity which it is the instrument of producing."43Although Mill acknowledged the success of the weaving industry in medieval India, his explanation for it reflected a view that was all too common in that era:

> It is an art to which the circumstances of the Hindu were in a singular manner adapted. His climate and soil conspired to furnish him with the most exquisite material for his art, the finest cotton which the earth produces. It is a sedentary occupation, and thus in harmony with his predominant inclination. [I]t requires little bodily exertion, of which he is always exceedingly sparing. But this is not all. The weak and delicate frame of the Hindu is accompanied with an acuteness of external sense, particularly of touch, which is altogether unrivalled, and the flexibility of his fingers is equally remarkable. The hand of the Hindu, therefore, constitutes an organ, adapted to the finer operation of the loom.44

In offering the above explanation, Mill approvingly quoted a similar argument offered by the historian Robert Orme, who reasoned:

> A people born under a sun too sultry to admit the exercises and fatigues necessary to form a robust nation, will naturally, from the weakness of their bodies (especially if they have few wants), endeavour to obtain their scanty livelihood by the easiest labours. It is from hence, perhaps, that the manufacturers of cloth are so multiplied in Indostan. Spinning and weaving are the slightest tasks which a man can be set to, and the numbers that do nothing else in this country are exceeding. 45

Although James Mill had his own ideological reasons for his views on India, such negative evaluation of Indian textile technology and the invocation of geographical and climatic factors to explain the presence of the cotton industry paints a picture of a technologically stagnant society. Although the technology employed in the textile industry appeared to be simple, the whole process of manufacture, from the preparation of the raw thread, the warping, the fixing of the warp and the loom, and the final stage of weaving, dyeing, and finishing was anything but simple and required a high degree of expertise.46Moreover, the technology itself was not devoid of innovations and was well suited to the demands of the society of that period. In the first instance, the development and application of "resists" during the dyeing process to confine colors to particular patterns on the fabrics and the use of "mordants" to "take" colors were innovative techniques, far superior to any other method of its time, and produced much better results than the simple color printing from wooden blocks, which had become popular in seventeenth-century Europe.47Finally, what was most innovative in this field was the perfection of techniques for ensuring the permanency of dyes transferred onto the fabrics. In fact the permanency of the dyes was one of the factors that ensured a good export market for Indian fabrics, and the set of techniques by which this was accomplished attracted the attention of early British observers. In this connection, a letter from a Dr. Helenus Scott, stationed in Bombay, to Sir Joseph Banks, president of the Royal Society, deserves to be quoted at some length:

> I have for several years past been attentive to the methods used by the natives of this country for dyeing their cotton cloths and I think I have discovered the singular circumstance by which they are enabled to give that permanency of colour which is so much admired. I am unable to give any theory of the operation of the chief substance they use and without which they can do nothing. It seems in all cases when a cloth is wetted with an infusion of it and a solution of alum, and then put into a vegetable colour to deposite something which has a strong attraction at the same time for the cloth and the colouring principle and which renders them ever afterwards inseparable. The natives have many methods of altering the colour of

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> vegetables or heightening their splendour simply by the additions of acids or of alum or of water in which iron had been infused. I know that to render these colours durable on the cloth (after separating a number of circumstances that only in appearance conduce to that end) they have no other method than the one I have mentioned. If this appears to you a matter of consequence as the cotton manufacturers are now in so flourishing a condition in England I shall at some future period communicate more particularly their method to you. 48

In the same letter, Dr. Scott expressed his frustration at being unable to obtain further details of other techniques, as "their knowledge of the arts is never communicated by writing nor printing nor their experience reduced to general laws by theory, the difficulty of information is again increased."49In another letter to Joseph Banks in 1792, Dr. Scott gave a detailed account of the use of a vegetable astringent for fixing colors on textiles, and he thought it would be so useful for

the English cotton industry, that he sent a sample of it to the Royal Society and was ready to incur the "expence of sending 3 tons of it at once." According to the letter to Sir Joseph Banks:

> In fixing some colours it has hidden powers which galls do not possess as I have experienced in the dyes of this country. Your chemists will see at once the general nature of this substance and your artists will find how far, by such an agent, they can produce the effects to which they have been accustomed; but it is only future experience that can discover those properties by which it may differ from every other astringent substance.50

Overall, Indian dyeing techniques and procedures for rendering them permanent, together with the preparation of a very wide range of vegetable dyes relied on quite sophisticated methods, which continued to be superior to other techniques until the invention and manufacture of artificial dyes in Germany. Depending on specific regional conditions, a number of innovations, such as the harnessing of water power for operating the cotton gin and the use of crank handles attached to the spinning wheels, were introduced.51

However, it is pointless to simply provide a catalogue of these innovations, as the issue of technology cannot be considered in isolation from the social structure in which it is embedded and which it reproduces and restructures. To characterize the textile technology of medieval India as "coarse" or "ill-fashioned," is to ignore the fact that prior to the imposition of prohibitive tariffs and duties by the British, products from the same "rudest contrivances" were not only comfortably supplying the demands of a vast domestic market but continued to exercise a virtual monopoly on the export trade. In fact the technology of textile production in medieval India was particularly well suited for the prevailing social structure. An abundant supply of labor and craftspeople in combination with a steady internal and export market for excellent quality textiles did not provide any economic incentives for dramatic innovations,

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which, in most cases, tend to be capital-intensive and labor-saving devices. The fact that there was an abundance of skilled labor in medieval India is evident from the firsthand accounts of a number of observers. For instance, Babar, the founder of the Mughal empire, observed in 1525 that "a good thing about Hindustan is that it has unnumbered and endless workmen of every kind." 52A hundred years later, the Dutch traveler Francisco Pelsaert commented that "a job which one man would do in Holland here passes through four men's hands before it is finished."53Similarly, in the early nineteenth century, Francis Buchanan remarked that "in India it is seldom that an attempt is made to accomplish anything by machinery that can be performed by human labour."54

A surplus of skilled labor, lack of any serious international competition, and, more significantly, the fact that the available technology and skill were producing "thread so fine, that the eye can hardly discern it" and cloth "so fine, that you could hardly feel it in your hand"55were not conditions that would encourage labor-saving technological innovations. Overall, the views of Mill, Baines, and Orme regarding the simple technology of India represented a comparison with the innovations in textile technology of Britain after the Industrial Revolutiona revolution partially precipitated by a number of social and not purely technical factors. As will be discussed later, major innovations in cotton textile technology in Britain, which were central to the Industrial Revolution, occurred partly as a consequence of attempts to create an import-substituting industry in the face of massive imports of Indian cotton fabrics. These social factors were ignored in Edward Baines's description of the British cotton industry as the "creature of mechanical invention and chemical discovery a spectacle unparalleled in the annals of industry" when compared to "its ancient history in the East, and its sluggish and feeble progress in other countries, until the era of invention in England."56

In addition to the production of cotton, which dominated the manufacturing sector in medieval India, there were a number of other enterprises that depended on sophisticated technological and practical scientific knowledge. The sections below provide a broad outline of the diverse range of such enterprises with the aim of elucidating the underlying scientific and technological knowledge and skills that made them possible. In the final section of this chapter, certain theoretical generalizations about the relationship between scientific and technical development and the social structure will be offered.

Mining And Metallurgical Industries

The existence of mining and metallurgical enterprises in ancient India is well documented.57The reports of a number of early British surveyors and archaeologists have provided ample evidence for the antiquity of both open pit and

deep shaft mining in many regions of India. In the southern Indian region of Mysore, a number of old workings, many up to 380 feet deep have been discovered. At a place called Hutti in the same region, a couple of shaft mines up to 640 feet deep have also been found. 58There is good evidence of prolonged and systematic mining explorations and there are several recorded instances in which old workings extend for miles along a reef.59The rocks at some of these sites are extremely hard, "making progress even for modern excavators with modern tools very slow."60The ancient techniques of mining and excavation included setting fires on the rock face and then sprinkling it with water, which would shatter the rocks. Ashes, timber, and charcoal frequently encountered in the old workings provide evidence of this method. Timbering was used in the galleries, and the shattered rocks were hauled to the surface by ropes and windlasses. The sides of the rock faces in the shafts have been worn smooth by prolonged rubbing with ropes, and archaeological excavations have unearthed a windlass at Hutti.61According to archaeologist Raymond Allchin, C-14 analysis of the objects recovered from the sites date the working of these mines to between the first century B.C. and the third century A.D.62

Although many copper, bronze, and iron objects have been excavated by archaeologists,63perhaps the most spectacular evidence of the practice of metallurgy in the ancient period is provided by the giant iron pillar of Delhi and the colossal Sultanganj copper statue of the Buddha, both dating from about 400 A.D. The iron pillar, which can be seen in Delhi today, is made of pure, rustless, and malleable iron. It measures twenty-three feet, eight inches in length and about sixteen inches in diameter, weighs over six tons, and must have been manufactured by some manner of welding.64After observing it in 1881, Valentine Ball, a geologist working in India remarked, "it is not many years since the production of such a pillar would have been an impossibility in the largest foundries of the world, and even now there are comparatively few where a similar mass of metal could be turned out."65Like the iron pillar, the Sultanganj statue of Buddha, made of pure copper and cast in two layers over an inner core, is also quite a colossus, measuring seven and a half feet in height and weighing about a ton.66Both these artefacts attest to the existence of complex metallurgical processes in use in ancient India.

The Production of Indian Steel, or "Wootz"

The tradition of metallurgy and mining continued in the medieval period, and Abul Fazal's text *Ain-i-Akbari*, which provides a rich account of sixteenth-century Mughal India during the reign of Akbar, refers to extensive mines of copper, iron, silver, and turquoise in various regions.67The same text refers to zinc mines being operated in Rajasthan,68a significant point since zinc was isolated and produced in Europe only in the eighteenth century.69The techniques

for production of metallic goods were quite developed, and, as the historian K. N. Chaudhuri has documented, specialized metal goods like swords, armor guns, and ornamental metalware were being exported to a number of west Asian countries in the medieval period. 70Although the techniques for smelting and producing copper, bronze, and, later, iron were present in a number of civilizations, the method of producing crucible-cast steel was discovered and perfected in India.

As recounted by C. E. Smith and R. J. Forbes in Charles Singer's monumental multivolume *A History of Technology*, "though crucible steel did not become important in Europe until Huntsman developed it commercially in 1740, it had been produced in India under the name *wootz*."71Observation of the method and process of the manufacture of crucible-cast *wootz* steel in India attracted the attention of a number of British surveyors in the 1970s. Detailed accounts of the method of manufacture were recorded and a sample weighing 183 lbs. was sent by Dr. Scott to Sir Joseph Banks. A note accompanying the sample stated that "it appears to admit of a harder temper than any thing we are acquainted with. I should be happy to have your opinion of its quality and composition."72Although the method of steel production was not based on any explicit knowledge of modern theoretical chemistry, it was, nevertheless, after years of experimentation, improvisation, and the accumulation of empirical knowledge that the method of roasting iron with "green wood" was perfected. According to one early description of the method recorded by a British surveyor:

> The Indian account of *Wootz*-making is, that pieces of iron and some green wood are inclosed (sic) in a crucible, and submitted to the heat of a furnace; the fire is urged by several bellows of a construction peculiar to the country; the wood is charred, the iron fused, and at the same time converted into steel. The metal is suffered to crystallize at the bottom of the crucible. [T]he chief peculiarity in this neat and ingenious method of steel-making, consists in the wood not being previously charred. [S]uch is then its extreme hardness, as to require to be heated from 30 to 40 degrees of Fahrenheit higher, in tempering, than the best English cast-steel.73

As emphasized in the above account, the key to successful iron production in India lay in the development of bellows, "a construction peculiar to the country," which supplied regular air blasts. These early accounts, which were dispatched to Britain, aroused considerable interest and even inspired a replication of the process under the patronage of the Royal Society. However, initial attempts at replication were not very successful, and, as J. Stodart put it, "the first attempts to forge Indian steel were attended with considerable difficulty. [E]nough however was then learnt, to warrant the conclusion that it possessed valuable properties."74The same observer agreed that "the experience of twenty-five years fully confirms the sanguine opinion then given,

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Wootz, when properly treated, proving vastly superior to the best cast-steel of Europe," and "is invaluable for surgical instruments, where mediocrity is not, at least." 75

The locally manufactured iron and *wootz* steel of precolonial India were utilized for the production of a number of objects, but it was particularly well known for the "Damascus" sword, made from steel with a high carbon content of 1.5 to 2 percent. Persian merchants traveled to the Deccan region of India to purchase steel made at the medieval iron foundries of Konasamundram and Dimdurti.76By the seventeenth century, cast-iron objects were being produced in the large foundries of Orissa, and Alexander Hamilton, in 1708, observed that "iron is so plentiful that they cast Anchors for ships in Moulds."77By the eighteenth century, a number of British observers found it worthwhile to record in great detail and send home the specific methods and procedures for manufacturing iron in India.78James Franklin's account of a furnace provides an elaborate description of each aspect of the technology and process involved in the manufacture of iron, and he concludes by questioning "whether any other furnace would compete with it."79In a similar vein, while discussing the quality of iron being produced by indigenous methods, Captain J. Cambell, the assistant surveyor general based at Madras, wrote that "from what I have seen of Indian iron, I consider the worst I have ever seen to be as good as the best English iron." And after putting the indigenously produced Indian iron through a number of rigorous tests, including a "severe trial which the hoop (Swedish iron) bears surprisingly," and, which "even the charcoal-made English iron will hardly bear," Cambell concluded: "There is hardly one of the above tests, which the good native iron of Southern India will not bear, and some iron which was produced in my own furnaces, has stood drawing out under the hammer into a fine nail rod not 1/10th inch thick, without splitting. An inch bar of good iron thus treated will bear a dozen blows of a heavy sledge hammer before it will break.80

Metallurgy and Military Technology

Increasing sophistication in metallurgical operations facilitated the manufacture of a wide range of firearms and artillery, a development that, according to the historian Irfan Habib, "represented the highest achievements of industrial technology during the sixteenth and seventeenth centuries."81Introduced in India sometime in the fifteenth century, the manufacture of cannons and muskets constituted one of the first "heavy industries" of the medieval period.82By the late sixteenth century during Akbar's reign, matchlocks were being manufactured. The chronicler of the period, Abul Fazl refers to an innovation in the design of the guns being produced at that time. Writing in 1595, he observed "they have so fashioned a gun that, without the use of the 'match' (*fatila-i*

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atish), but with just a slight movement of the trigger (*masha*), the gun is fired and the pellet (*tir*) discharged." 83The above account fits the description of a wheel lock, an Italian invention of about 1520, and its production in sixteenth-century India represents a significant achievement.84The production of a gun barrel is a technically sophisticated operation, as it has to be both strong enough to withstand the explosion and well enough aligned to ensure accuracy for

the projectile. In the production of the barrel in Mughal India, the technique adopted was similar to that employed in Europe. Thus, instead of making a barrel simply by bending and joining the edges of a sheet of iron flattened by hammering, it was produced by using rolls of flat iron, twisted around with one edge running over the other, welded and then bored from inside.85Overall, the production of artillery pieces was well established in sixteenth-century India, and by 1663, the French traveler Francois Bernier could write that "among other things, the Indians make excellent muskets, and fowling-pieces."86The same observer furnished details about the artillery of the Mughal army, an account that provides a good glimpse of the industry in medieval India. According to Bernier, the "artillery is of two sorts, the heavy and the light, or, as they call the latter, the artillery of the stirrup."87The heavy artillery consisted of "cannon, mostly of brass," and "field-piece[s] of the size of a double musket, attached on the back of the animal [camel], as much in the same manner as swivels are fixed in our barks."88The "artillery of the stirrup" consisted of "small field-pieces, all of brass each piece mounted on a well-made and handsomely painted carriage, containing two ammunition chests."89

Although Bernier was writing in the mid-seventeenth century, bronze cannons were being cast by Indian craftsmen from at least the time of the reign of Babar, or the early sixteenth century. By the end of the sixteenth century, some of the heaviest guns were being cast in bronze in India, the most famous of these being the *Malik Maidan*, which had a length of thirteen feet, four inches, diameter of five feet, five inches at the muzzle and two feet, four and a half inches at the bore.90A seventeenth-century foundry for casting heavy cannons has also been found in Amber, Rajasthan. Because the arsenal and its working equipment remained sealed long after the workshops had cease to operate, the foundry is still in a remarkable state of preservation: the brick furnace, equipped with bellows and an overhead ventilation system; gun molds for producing large-bored guns up to two meters long; and gigantic lathes can be seen in a fortress near the town of Amber.91However, by the late seventeenth century, these heavy bronze cannons were becoming anachronistic, mainly because they lacked mobility and accuracy. Taking account of the fact that it was hard to maneuver and required "15,000 pounds of powder to charge it," the Italian traveler Pietro della Valle described the heaviest of cannons, the *Malik Maidan* as being "useless for war, and serv[ing] onely [sic] for vain pomp."92Nevertheless, it appears that even though these heavy guns were of no use on the battlefield, they continued to function as visible symbols of royal power.

The Use of Rockets in Warfare

Although, as Needham 93has documented, gunpowder and rockets were Chinese innovations, the latter was in use in India as early as 1398 during the confrontation between Timur (Tamerlane) and Sultan Mahmud V at the seige of Delhi.94By the sixteenth century, rockets, or *bans*, were being used in India as "standard weapon[s] upon the battlefield."95They are known to have been used by the Mughals, Marathas, Poligars, Sikhs, Rajputs, Rohillas, Bijapuris, etc. Francois Bernier's account of the battle of Samugarh in mid-seventeenth-century Mughal India describes the use of "*bannes* which are a sort of a grenade attached to a stick, and which were thrown, from various parts of the line, among the enemy's cavalry, and which produced the effect of terrifying the horses, and sometimes of killing the men."96Bernier's account is corroborated by the Venetian traveler Niccolao Manucci's description of the same battle where the combatants used "bombs with tails."97An early English account of a battle that Shah Shuja lost in 1659 observed that the "chiefest occasion of his overthrow was by a stratagem of war which they use here, of fireworks made of bamboos (more desperate by farr, as they report, then [sic] granadoes), which his enemies were well provided with, and hee on his parte had but few."98These accounts make clear that not only were indigenous rockets being used on some medieval Indian battlefields, but they were effective enough to decide the outcome of wars. The use of rockets was particularly favored by the Marathas and the armies of Haidar Ali and Tipu Sultan. Historian of science Frank Winter estimates that Tipu Sultan deployed as many as six thousand *jurzail-burdars*, or "rocket-men," during the battles of Seringapatam (1792 and 1799) against the armies of the English East India Company.99

The *ban*-rockets used against the British by Tipu Sultan in the late eighteenth century served as models for the "Congreve" rockets developed in England by William Congreve in the early nineteenth century. Although rockets had been used on the battlefields of Europe as early as 1379, as the battle of the Isle of Chiozza in Italy suggests, they gradually disappeared, possibly due to the rapid advancements in the design of conventional firearms like the rifle and cannon.100During the same period, the design of rockets continued to evolve in India. They were made of bamboo, with iron cylinders containing combustible materials and light grenades attached to them. The Indian innovation in the design of rockets was the use of metal, instead of many layers of paper, in the construction of the rocket chambers. As a consequence of this technological innovation, the rockets were able to withstand higher combustion, resulting in higher

performance pressures.101It was this technological innovation in the design of the rocket chamber that was incorporated into the "Congreve rockets" and led to a "virtual rebirth of war rockets and general

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rocket technology in Europe." 102As Frank H. Winter has said about this transfer of technology in the late eighteenth century, "Indian war rockets, crude though they may have been served as a technological bridge or catalyst between the ancient or medieval world and the modern age of industrial revolution."103

The Evolution of the Stirrup

Closely related to the development of military technology is the evolution of the stirrup, which revolutionized the methods of warfare and the organization of armies, and stimulated a number of social and cultural changes. As historian of technology Lynn White Jr. has observed,

> few inventions have been so simple as the stirrup, but few have had so catalytic an influence on history. The requirements of a new mode of warfare which it made possible found expression in a new form of western European society dominated by an aristocracy of warriors endowed with land so that they might fight in a new and highly specialized way. Inevitably this nobility developed cultural forms and patterns of thought and emotion in harmony with its style of mounted shock combat and its social posture.104

In a similar vein, Joseph Needham quipped, "just as Chinese gunpowder helped to shatter European feudalism at the end of this period, Chinese stirrups had originally helped set it up."105One need not be a technological determinist to appreciate the complex chain of social and cultural changes that the invention of the stirrup left in its wake.

The "foot stirrup" was a Chinese invention, in common use in Hunan province by the early fifth century, and is mentioned in Chinese literature from 477 A.D.106However, the earliest documented evidence of the use of "toe stirrups" comes from a number of Indian sculptures at Sanchi, Mathura, and Pahaora, which date from the second century B.C.107The "toe stirrup" appears as a "loose surcingle behind which the rider's feet were tucked, and later [as] a tiny stirrup for the big toe alone."108A Kushan engraving from c. 100 A.D. depicts a booted rider with feet supported by rigid hooks from the saddle. Although this innovation might not have survived since hooks might easily drag a fallen rider, it demonstrates that the search for adapting the "big-toe stirrup" was undertaken early on in India.109The early form of Indian stirrups probably served as footrests and provided partial balance, but not enough support to enable the riders to stand up while on the battlefield.110However, these early ideas and inventions, especially the "big-toe stirrup," were the precursors of the Chinese iron "foot stirrups." As Lynn White Jr. has argued, it seems that the Indian concept and the innovation of the stirrup spread to China with the first waves of Buddhist missionary activity, where it emerged in the fifth century as the first full-fledged "foot stirrup."111According to White, "the big-toe

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stirrup spread wherever ancient India had contact with people on the east as far as Timor, and the Philippines and on the west to Ethiopia." 112Overall, stirrups were unknown in the ancient Near East, Greece, and Rome, and were introduced to these culture areas via central Asia, toward the end of the seventh and early eighth centuries. Archaeological evidence suggests the early eighth century as the probable date of the diffusion of the stirrup to western Europe. In any case, the idea as well as the first rudimentary "big-toe stirrup" evolved into a full-fledged "foot stirrup" in China before being diffused to western Europe, where, in combination with a number of specific social conditions, it played a role in the emergence of feudalism.

Agricultural Technology and Methods of Cultivation

Despite the presence of a wide range of industries and technology, precolonial India was predominantly an agrarian society. Surplus from the agrarian sector and extensive trade provided support for the various industries. For example, the development of the cotton industry would not have been possible without the practice of sophisticated agricultural techniques for the cultivation of a wide variety of cotton crops. In any case, a majority of the Indian population was

involved in agricultural pursuits, an activity based on extensive naturalistic knowledge and the use of a range of technological devices and instruments.

As in the case of other craft industries, some early British observers commented on the apparent "rudeness" of Indian agricultural technology and implements. The type of plough in use in India as well as the specific method of ploughing attracted considerable attention on this score. The plough was considered "imperfect in the extreme," such that "no draughtsman can represent in an adequate manner the imperfection of this and the other instruments."113Other observers depicted Indian ploughs as "wretched in construction"114and "grubbers which stir up the soil without inverting it."115In describing the action of the plough, Rev. William Tennant remarked that "only a few scratches are susceptible here and there, more resembling the digging of a mole than the work of plough."116British colonial historian Henry M. Elliot, while criticizing the preceding account as "prejudiced and superficial," hesitated in using the term "plough" as he was unsure "if an instrument may be dignified by that name which has neither coulter to cut the soil nor mould board to turn it over."117

Unlike other more astute British observers who offered a more balanced evaluation of Indian agricultural technology, these early commentators completely ignored the local ecological and topographical context of the practice of agriculture. There is no doubt that the ordinary Indian plough appeared to

be a technologically simple implement. Nevertheless, the early observers erred in equating the simple construction of the plough with diminished capability or efficiency. However, there were some British observers who attempted to acquire a more sophisticated understanding of the relationship among scientific knowledge, technology, and the wider ecological and environmental context of Indian agriculture. The response of one Major-General Alexander Walker to the early accounts of the technology and practice of agriculture represents one of the few attempts to relate the agricultural technology of medieval India to the social context of its use. In Walker's words:

> It has been objected to these instruments that they are simple, clumsy and rude. This does not however make them less useful. Simplicity cannot surely be counted a fault; in some of our districts the plough is by far too complicated a machine. In Guzerat it is a light and neat instrument. It has no Coulter but has a sheathing or iron: the furrows of the Husbandsman are as straight as a line, and of sufficient depth to produce the most abundant crops. This is the real and only useful test of farming. The form of the plough in Malabar is nearly the same, but it is still lighter, and more rudely constructed. A man may carry one of them on his back. They are nevertheless convenient, accommodated to the soil and the labour. The structure of these instruments, all over India is very simple; but they answer the purpose of the Husbandsman where the soil is light, unobstructed by stones, and softened with water. In a climate where the productive powers are so great, it is only necessary to put the seed a little way into the ground. If it was buried deeper, it would rot and decay before it could germinate, or it would remain dormant in the earth. It must be a strong proof that the Indian plough is not ill adapted for its purpose, when we see arising out of the furrows it cuts, the most abundant and luxurious crops. What can be desired more than this? 118

It is quite evident from the above account that the ordinary Indian plough, which, surprisingly, attracted so much comment from the English observers, was well adapted to the specific topographical conditions of the region.

However, the ordinary Indian plough was not the only agricultural implement in use. Depending on the local topographical conditions and soil types, three other types of ploughs were in use. One of these was the "drill plough," which a British observer, Captain Thos. Halcott "had until lately imagined to be a modern European invention," discovering it is "in general use here [India], and has been so time immemorial."119The drill plough represented an Indian technological innovation for the cultivation of tobacco, cotton, and the castor oil plant. According to Henry M. Elliot, it had "been introduced into English field husbandry only within the last century."120Apart from the "drill plough" and the "common plough," Thos. Halcott described two other indigenous innovations in ploughing equipment. One of these he described as having a "horizontal share," which immediately follows the drill plough at

work and "operates by agitating the earth so as to make the sides of the drills fall in, and cover the seed-grain, which it does so effectually as scarcely to leave any traces of a drill." 121According to Halcott's account, a fourth indigenous device "is used after the corn is about eight or ten inches high. It cuts up the weeds between three drills at once, and earths-up the roots of the corn at the same time."122In a letter to a friend in England, Halcott noted that "I cannot, by writing, give you an adequate description of the three ploughs, but will send you a set of them, if you wish it, accompanied by a man who has been in the practice of working them."123He requested his friend to forward the ploughs to the Board of Agriculture in London, as he was convinced that the Indian design provided a "remedy for the defect complained of in the English drill plough." Describing the operation of the Indian drill plough in detail, Halcott expressed surprise at "how soon an acre is sown in this way" and urged for its introduction in England because "a plough of this kind would be but a few shillings, whereas the [English] patent drill is an expensive machine."124The set of three ploughs was received by the Board of Agriculture in London, but unfortunately no account of the consequences of this eighteenth-century transfer of technology from India to England exists. In an ironic twist to Hugh Murray's observation that "no draughtsman can represent in an adequate manner the imperfection of this and other instruments," elaborate drawings of the set of three ploughs were reproduced in the first volume (1797) of the *Bulletin of the Board of Agriculture*.125

Together with the drill plough, another indigenous Indian innovation in the field of agricultural technology was the rolling mill based on the "parallel worm" for crushing sugarcanes. The sugar mill was based on a similar principle as the cotton ginanother indigenous innovationexcept for the fact that the rollers in the former are mounted so as to rotate horizontally, whereas in the latter case they rotate vertically. Joseph Needham has argued that both these devices "were distinctively Indian contributions" and the earliest reference to the sugar mill based on rotating horizontal rollers comes from the first century A.D.126The device for crushing sugarcane consisted of two wooden rollers, with the main roller having ridges that fit into the grooves of the secondary roller. The main roller was rotated by an axle attached to a pair of oxen, which were driven around it, and the alignment of the gears and grooves sets the secondary rollers in motion. The canes were thrust in between the rollers, and the juice would be collected in a container attached underneath. By the medieval period, these sugar-milling devices were quite common in most parts of the country and were described in detail by a number of travelers, including Carieri, who in 1695 observed "Sugar Cane's Press'd between two great wooden Roulers, turn'd about by Oxen, whence they came out thoroughly squeez'd."127In addition to the sugar mill, a second method included the use of mortar and pestle, but this was ill suited for cane which had to be sliced first into short pieces and then dropped into the mortar.128

Overall, agricultural technology and techniques of crop cultivation were quite developed and adapted to the local environmental and topographical conditions. Crop rotation was universally practiced, 129and the numerous ploughing and cross ploughing of the land, which was taken by the early English observers to be a proof of the imperfection of the plough, was in fact practiced both to "extirpate weeds [and] to loosen the soil, apt to become hard and dry under a tropical sun."130The practice of sowing different species of seeds in the same field, which was initially censured by early British observers, was later found to be based on practical experience and was extremely beneficial for the crops. Such practical knowledge was also preserved in certain texts where some of the consequences of planting different crops in the same field were distinctly enunciated. Thus, Amanullah Husaini, writing sometime in the sixteenth century, recorded that crops of *baqila* bean (fava sativa), *baqila-i misri*, or Egyptian bean, imparted fertilizing qualities to the soil, a fact now recognized as "nitrogen fixation" by leguminous plants.131According to a British observer in the later years, a "plant called *sota gowar*, is sown broadcast with sugar cane [and it] serves as a shelter to the sugar cane, from the violent heat of the sun, during the most scorching season of the year."132

Irrigation Technology

Closely allied with agriculture is the issue of irrigation, and India has long been identified as one of the archetypical "hydraulic societies." A diverse range of thinkers, including Hegel, Montesquieu, Marx, and Wittfogel have attempted to link the elaborate system and network of artificial irrigation in India with a particular form of government, or "Oriental despotism"a characterization that has generated intense discussion.133While evaluation of this view is not attempted in this section, there is ample archaeological and inscriptional evidence for the presence of extensive networks of artificial irrigation patronized by various rulers and systems of government in ancient and medieval India.

The construction and maintenance of large artificial tanks and canals for purposes of irrigation constitute examples of

sophisticated engineering skill in medieval times. Large-scale irrigation in medieval India was of two kinds: tanks created by embankments, from which canals of relatively short lengths would carry water to the fields, and longer canals emanating from undammed rivers and traversing fairly long courses. The gigantic tanks created by embankments were found mainly in the Deccan and central India and were patronized by the local Hindu rulers and chiefs, while the extensive systems of long canals were laid out by the pre-Mughal and Mughal rulers in northern India.134

A good example of the construction of giant tanks created by the building of embankments was the Madag Lake in the Dharwar district. The construction of this tank was patronized by the Vijayanagara rulers of south India in

the fifteenth and early sixteenth century. A nineteenth-century British account provides some indication of the scale as well as the engineering skills involved in the building of this medieval irrigation project:

> The makers of the lake intended to close the gap in the hills through which the Kumudvati feeder of the Tungabhadra flows into Kod. This was accomplished by throwing up an earthen embankment, now about 800 feet thick at the base and 100 feet high, faced towards the lake with huge stone blocks descending in regular steps from the crest of the embankment to the water's edge. Two similar embankments were also thrown across other gaps in the hills to the right and left of the Kumudvati valley to prevent the pent-up waters escaping by them, and a channel was cut along the hills for the overflow of the lake when it had risen to the intended height. Each of the three embankments was provided with sluices built of huge slabs of hewn stones for the irrigation of the plain below, and two of these remain as perfect as when they were built. These sluices were built on the same principle as other old Hindu local sluices, a rectangular masonry channel through the dam closed with a perforated stone fitted with a wooden stopper. But, as the sluices had to be in proportion to the size of the lake, instead of the small stone pillars which in ordinary works carried the platform over the stopper, the supports were formed of single stones weighing about 20 tons each. When full, this lake must have been 10 to 15 miles long and must have supplied water for the irrigation of a very large area. The neighbouring hills still bear traces of vast cutting for materials and of the roads by which it was brought to the site. 135

The above account provides just one example of the tradition of royal patronage as well as the utilization of considerable hydraulic engineering skills for the construction and maintenance of large tanks and reservoirs for purposes of irrigation in the Vijayanagara empire.136A major innovation, which made possible the construction of waterproof walls and floors of the dams, was the use of lime mortar, a fact that evoked a lot of interest amongst British observers. An early eighteenth-century British account of the use of lime mortar, or *chunam*, and other substances concludes: "a Plaister thus made is more durable than some soft stone, and holds the Weather better in India, than any of the Bricks they make there."137In a series of letter to the president of the Royal Society, another English observer noted:

> For works below the surface of water I think the Indians have an excellent method of preparing their *chunam*. In a few hours it acquires great solidity and especially the part of it that binds together the large stones which face the walls. One of the chief ingredients is a kind of unrefined sugar which appears by Mr. Bergman's experiments to contain more of the disengaged saccharine acid than refined. With this and some other substances the *chunam* is carefully mixed for a length of time and is occasionally wetted with a solution of the sugar in water. As far as I can learn no one has yet practiced a method similar to that used in this country.138

That the tradition of building large reservoirs and tanks had antecedents in remote antiquity is evident from the archaeological remains of the Sudarshana Lake, created by the construction of a dam and tank undertaken during Chandragupta Maurya's reign (c. 320 B.C.). The same tank was later furnished with canals for irrigation during the rule of Asoka (268231 B.C.). 139There was also the mammoth reservoir in Bhojpur, built sometime in the mid-eleventh century. Created by building a series of damns, the lake covered an area of 250 square miles and was intact at least until the late nineteenth century.140

The reign of Firuz Shah (13511388) in northern India, was particularly marked by the construction of a number of irrigation systems. Although other rulers from the Tughluq dynasty had constructed a number of lakes, tanks, and cisterns

around Delhi and Daulatabad, Firuz Shah was one of the first rulers of the Delhi sultanate to initiate the construction of reservoirs and dams for storing rain water for irrigation in areas where canal water was not available.141According to Firishta, the chronicler of the period, Firuz Shah constructed thirty huge reservoirs in areas where canal water for irrigation was not available. Afif, another chronicler writing in the same period, has listed seven such reservoirs in the vicinity of Delhi alone.142For the Mughal period, too, there is evidence of such tanks, reservoirs, and artificial lakes in a number of areas. Abul Fazl writing in 1595, under the reign of Akbar, describes a number of tanks in the Mewar region, the most famous one which was about forty miles in circumference,143being at Udaisagar. Describing a dam on a lake in the city of Jannatabad in Bengal, Abul Fazl notes that "were the dam that confines it to break, the city would be under water. [A]bout a *kos* to the north of the fort, is a large building and a reservoir, monuments of great antiquity."144Finally, Jean Baptiste Tavernier, the French traveler who visited India in mid-seventeenth century, in writing about the Golconda region, observed: "dams and banks [that] are sometimes half a league long: and after the rainy seasons are over, they open the sluices from time to time to let out the water into the adjacent fields, where it is received by divers little channels to water particular grounds."145

The second type of irrigation enterprise, comprising extensive networks of canals emanating from undammed rivers were found in northern India and were constructed mainly during the immediate pre-Mughal and Mughal period. The construction of large artificial canals in the medieval period seems to have begun during the reign of Alauddin Khilji in the final decades of the thirteenth century. In this period a number of canals were built, with expenses for the construction coming from taxes imposed on the peasantry. A *nishan* (official document issued by a governor) from the period contains explicit directions to subordinate officers to supervise repair work on old canals, which are cited by name as: *Ju-i-Nasirwah*, *Ju-i-Qutbwah*, and *Ju-i-Khidrwah*.146The same *nishan* instructs an officer, Ali Quli, to collect money

from the cultivators to meet the expense of desilting the canals so that the *baitul-mal* (state treasury) would not have to bear the burden. 147The activity of building long irrigation canals received further impetus under the rule of Firuz Shah in the second half of the fourteenth century. According to one account from Firuz Shah's time, an intricate system of canals, "one hundred and twenty miles long, were led off from the rivers, the Jamuna and the Ganges. The water, flowing through them, irrigated the desert and desolate tracts where no well or lake existed. The depth and width [of certain canals] has made the use of boats possible; people travel in boats, covering distance from one to the other place."148Several other canal systems, most of them in the now agriculturally productive regions of Punjab and Haryana, were constructed under the reign of Firuz Shah. These included a system of double canals, which drew their headwaters both from the Jamuna and Sutlej Riversthe Sutlej canal, named Ulugh Khani, flowed through the areas of Ropar and Sirhind, and met the Jamuna canal, called the Rajiwah, which passed through the Karnal area. Another important canal was the *Ju-i-Firozabad*, which originated from the Jamuna River and irrigated agricultural lands around the capital city of Firozabad.149All these canals were partly funded by the levy of an irrigation tax (*haq-i-sharb*), which amounted to about one-tenth of the agricultural produce. Funds raised from this levy went towards maintenance and repair of the canals, an activity kept up by the later rulers of the Delhi sultanate.150Overall the construction of an intricate system of canals enabled the cultivation of two crops a yearautumn and winter, or *kharif* and *rabi*in regions where hitherto only the *kharif* crop had been possible.151

The construction of new irrigation canals as well as the repair and maintenance of existing ones continued during the Mughal period. Firuz Shah's canals were repaired extensively during the reign of Akbar and later desilted during Shahjahan's rule.152Under Shahjahan's rule, the construction of the *Nahr-i-Faiz*, a canal over 150 miles long carrying water from the Jamuna River at Delhi, was a considerable achievement for medieval times. In William Francklin's account, penned in 17931794, the canal was described as "fertilising in its course a tract of more than ninety miles in length [and] as it ran through the suburbs of Moghul Para, nearly three miles in length, [it] was twenty-five feet deep, and as much in breadth, cut from the quarry of solid stone."153During this period, a number of natural canals, formed by the constant changes in the course of rivers, were also deepened, desilted and connected with the active river systems to facilitate irrigation. In addition to the archaeological remains and accounts from the Mughal period, further evidence for the organized construction of canal systems comes from administrative documents. One of these documents refers to the appointment of a canal superintendent (*mir-i-ab*) and requires the appointee to "dig new channels (*nala*), clear the old channels, and erect bunds on flood torrents (*band-i sail*)," and to ensure the equitable distribution of canal water among the cultivators.154Furthermore, a

number of new dams and reservoirs were constructed for purposes of irrigation. During Shahjahan's reign, there is documentary evidence of proposals for an advance of fifty thousand rupees to cultivators in Khandesh and Berar, for the construction of dams. 155

It would appear from the above account that large-scale hydraulic enterprises constituted the only source for the irrigation of agricultural lands in medieval India. However despite the prevalence of many such large-scale hydraulic projects and the frequent characterization of medieval India as the archetypical "hydraulic society," most of the agricultural lands received their water supply from a number of local and small-scale irrigation devices. These localized sources included deep wells, the Persian wheel, or the *saqiya* or *charkhs*, and the *noria*, or *dulab*. The Persian wheel, or the *saqiya*, comprises three wheels and a beam horizontally attached to a toothed wheel outside the well on one end, and yoked to a pair of bullocks on the other. With the help of the movement of the bullocks in a circular power, buckets attached to a chain at regular intervals carry the water up from the deep well to the surface and are channeled into the fields. The *noria* was a similar device, with buckets attached to a rope and a wheel, but instead of drawing water from deep wells, it operated on open water surfaces like rivers, tanks or lakes, and the wheel was turned horizontally by human hands instead of animal power.156

While the *saqiya*, or the Persian wheel, was most probably introduced in India from the Near East, its widespread use in the thirteenth century is supported by a wide range of documentary evidence.157As setting up the *saqiya* involved a fair amount of expenditure, it was generally in use in agriculturally prosperous areas, or under state patronage. For instance, according to the *Sirat-i Firuz Shahi*, a number of these devices were installed in the area around the capital city of Firozabad under the reign of Firuz Shah (13511388).158The classic description of the use of the *saqiya* in northern India comes from the first Mughal ruler Babar's memoirs, penned in 1525:

> In Lahor, Dibalpur and those parts, people water by means of a wheel. They make two circles of ropes long enough to suit the depth of the well, fix strips of wood between them, and on these fasten pitchers. The ropes with the wood and attached pitchers are put over the well-wheel. At one end of the wheel-axle a second wheel is fixed, and close to it another on an upright axle. This last wheel the bullock turns; its teeth catch in the teeth of the second, and thus the wheel with the pitchers is turned. A trough is set where the water empties from the pitchers and from this the water is conveyed everywhere.159

From the detailed description provided by Babar, it is clear that the device was a novelty for him. Although some scholars have adduced documentary evidence to argue for the presence of the *saqiya* in ancient India, the historian A. L. Basham has argued that "the Persian wheel turned by an ox, is nowhere clearly mentioned in early sources, though it may have been used."160

Unlike the *saqiya*, another irrigation device, the *noria* was an indigenous Indian innovation. As Joseph Needham has pointed out, there are references in Pali to a *Cakkavattaka* (turning wheel) and commentaries on *arahatta-ghati-yantra*, or a machine with water-pots attached to it. 161Irfan Habib also agrees with the documentary evidence that indicates that the device known as the "*araghatta* or *ghati-yantra* was in use at least since the time of Christ."162Finally, a Buddhist text dating from the second century B.C. to the second century A.D., records an instruction from the Buddha to Ananda to make a *mandala* like a waterwheel so as to show the cycle of rebirths.163These factors, together with other documentary evidence, lead Needham to conclude that "provisionally we may adopt the hypothesis that it was invented in India, reaching the Hellenistic world in the 1st century and China in the 2nd."164In any case, the *noria*, known in contemporary India as *rahat*abbreviated from the *arahatta-ghati yantra*was widespread as an irrigation device in medieval India as is evidenced by a number of accounts from the period.165

Overall, the construction of large-scale hydraulic enterprises was patronized by a number of rulers in medieval India. The maintenance, repair, and building of projects fluctuated, depending on the political fortunes of particular dynasties as well as the general conditions of political and social stability. The prevalence of these irrigation enterprises over long periods of time had a number of economic and social consequences. For example, Punjab, one of the most agriculturally

productive areas of modern India, was largely a desolate region in the early medieval period. But between the eleventh and sixteenth centuries, largely as a consequence of the massive irrigation projects, extensive land reclamation occurred, transforming a largely pastoral community into an agricultural one. The overall consequence of the extension of irrigation in the Indus basin, was the transformation of a previously pastoral community and people into peasantry of the breadbasket of India.166

Creative Synthesis: The Social Organization and Practice of Medicine in Medieval India

The etiological principles and practice of the *Ayurvedic* system of medicine in ancient India have been discussed in some detail in the previous chapter. Although the *Ayurvedic* system continued to be patronized in the medieval period,167there was also an influx of new medical doctrinesassociated with Averroes, Avicenna, and Galen, among otherswhich contributed to the evolution and consolidation of the *Unani* system of medicine.168*Unani*, which literally means Greek and is probably a corruption of the term "Ionian," represented a creative synthesis of indigenous *Ayurvedic*, Greek, and west Asian medical systems and doctrines. During the period of the Delhi sultanate

the *Unani* system of medicine was patronized by a number of rulers. Under the patronage of Muhammad bin Tughluq (d. 1351 A.D.), over seventy dispensaries and hospitals were established in the vicinity of Delhi alone. A number of medical treatises from that period have been recovered, including the encyclopaedic *Majmu'-i Diya'i*, which runs into 221 folios and draws on the doctrines of Avicenna, Galen, *Ayurveda*, and a number of west Asian thinkers. 169The practice of *Unani* medicine was extensively patronized by Firuz Shah, who reorganized the hospitals and dispensaries founded by his predecessors. Firuz Shah also founded a major hospital in Delhi named Dar al-Shifa, which incurred an expense of over 3.6 million *takas*.170The period also witnessed the composition of a number of medical treatises like the *Rahat-al-insan, Shifa al-Khani, Tibb-i Shahabi and Shifa-i Mahmudi*.171The *Shifa-i Mahmudi*, which is a translation of a key *Ayurvedic* text, the *Astanga Hrdya*, together with other such texts, contributed to a synthesis of the various medical doctrines, which led to the systematization of the *Unani* system of medicine.

The treatise *Tibb-i Shahabi* was composed in verse and was probably one of the manuscripts that led Bernier who had spent twelve years (16561668) in India, to remark that "on physic they have a great number of small books. The most ancient and the most esteemed is written in verse." Bernier went on to comment that "their practice differs essentially from ours," and after describing some of the principles and methods of treatment, he observed that "whether these modes of treatment be judicious, I leave to our learned physicians to decide. I shall only remark that they are successful in Hindoustan."172

Surgical Procedures in Medieval India

A number of early eighteenth-century accounts of English observers provide fascinating details about the practice of intricate medical procedures and surgical operations in India. According to Colonel Kyd, the founder of the Calcutta Botanic Gardens, "In Chirurgery (in which they are considered by us the least advanced) they often succeed in removing ulcers and cutaneous irruptions of the worst kind, which have baffled the skill of our surgeons, by the process of inducing inflamation and by means directly opposite to ours, and which they have probably long been in possession of."173Similarly, Helenus Scott in his regular correspondence with Sir Joseph Banks provided an account of a surgical procedure to treat cataracts: "They practice with great success the operation of depressing the chrystalline lens when become opake and from time immemorial they cut for the stone at the same place which they now do in Europe. These are curious facts and I believe unknown before to us."174Two years later, Dr. Scott, in another letter to Joseph Banks, referred to a "paper on putting on noses on those who have lost them" and promised to "send you by the later ships some of the Indian cement for uniting animal parts." On

January 19, 1796, Scott sent Banks samples of a number of substances, including Indian steel with a note: "In this packet too you will find a piece of *Caute*, the cement for noses." 175Although these references to the substance and method for putting severed parts together have not been followed up in any detail, the ancient *Ayurvedic* text, the *Susruta-Samhita*

does contain fragmentary references to roughly similar procedures.

Indigenous System of Inoculation against Smallpox

Perhaps the most interesting of the early accounts of medical practice are the detailed descriptions of the indigenous method of inoculation against smallpox in eighteenth-century India.176Writing in 1737, one British observer noted that "the operation of inoculation called by the natives *tikah* has been known in the kingdom of Bengall as near as I can learn, about 150 years."177The most complete account of the procedure was offered by Dr. J. Z. Holwell in a 1767 address to the College of Physicians in London. Holwell who practiced surgery in Calcutta and whose accounts of India attracted the attention of Voltaire, observed:

> Inoculation is performed in Indostan by a particular tribe of Bramins, who are delegated annually for this service from the different Colleges of Bindooband, Eleabas, Banaras, &c. over all the distant provinces; dividing themselves into small parties, of three or four each, they plan their travelling circuits in such wise as to arrive at the places of their respective destination some weeks before the usual return of the disease.178

Holwell proceeded to describe the intricate details of the actual procedures adopted for inoculation:

> Previous to the operation the Operator takes a piece of cloth in his hand, and with it gives a dry friction upon the part intended for inoculation, for the space of eight or ten minutes, then with a small instrument he wounds, by many slight touches, about the compass of a silver groat, just making the smallest appearance of blood, then opening a linen double rag takes from thence a small pledgit of cotton charged with the variolous matter, which he moistens with two or three drops of the Ganges water, and applies it to the wound, fixing it on with a slight bandage, and ordering it to remain on for six hours without being moved.179

Holwell also described specific postinoculation procedures and regimens against which he was initially "prejudiced but a few years experience gave me full conviction of the propriety of their method. [T]his influenced my practice and I will venture to say, that every gentleman in the profession who

did not adopt the same mode, have lost many a patient, which might otherwise have been saved." 180

From a scientific point of view, what is particularly significant is that, according to Holwell, the medical practitioners were aware of the causative principles underlying the disease of smallpox and the practice of inoculation. Based on extensive conversation with the practitioners, Holwell concluded:

> They lay it down as a *principle* that the *immediate* cause of the small pox exists in the mortal part of every human and animal form; that the *mediate* (or second) *acting* cause, which stirs up the *first*, and throws it into a state of fermentation, is multitudes of *imperceptible animalculae* floating in the atmosphere; that these are the cause of all empidemical diseases, but more particularly of the small pox. That when once this *peculiar* ferment, which produces the small pox, is raised in the blood, the *immediate cause* of the disease is totally expelled in the eruptions, or by other channels; and hence it is, that the blood is not susceptible of a second fermentation of the same kind.181

Holwell also described a number of other procedures that were effective in curing full-blown smallpox, before concluding that "since this practice of the East has been followed without variation, and with uniform success from the remotest known times, it is but justice to conclude, it must have been originally founded on the basis of rational principles and experiments."182

The practice of medicine and surgery was successful enough for the physicians to be accorded a fairly high status in medieval Indian society. In some regions the physicians were allowed to have hats or umbrellas carried over thema practice that symbolized high social status and prestige. Thus, John Huyghen van Lichschoten, who lived in Goa for five years (15831588) observed:

> There are in Goa many Heathen phisitions which observe their gravities with hats carried over them for the sunne, like the Portingales [Portugese], which no other heathens doe, but onely Ambassadors, or some rich Marchants.

> These Heathen phisitions doe not onely cure there owne nations and countrimen but the Portingales also, for the Viceroy himselfe, the Archbishop, and all the Monkes and Friers doe put more trust in them then in their own countrimen, whereby they get great [store of] money, and are much honoured and esteemed.183

Apart from demonstrating the successful practice of medicine, the above account also establishes the fact that in certain regions physicians constituted a distinct occupational category or "profession" as early as the sixteenth century. Overall, it is evident that the practice of medicine flourished in medieval India, partly due to the patronage extended by some rulers. By the sixteenth century, the practice of medicine had also become established as a semi-independent occupation, and the practitioners were paid for their work.184

Astronomy, Astrology, and Patronage: The Science of the Heavens in Medieval India

The above account has focused mainly on a discussion of a number of technologies and industries in medieval India. Even while keeping in mind the earlier qualification that it may be hard to distinguish between science and technology prior to the Industrial Revolution, medieval Indian society exhibited a fair degree of development in science. The development of scientific thinking was especially evident in the field of astronomy. Due to extensive patronage extended by a number of Mughal rulers, medieval Indian society offered a conducive climate for the development of the indigenous as well as central and west Asian astronomical traditions.

A number of factors contributed to the patronage of astronomy by the Mughal rulers. Significant aspects of the lives of people were partly influenced by astrological considerations, which themselves depended on an accurate knowledge and understanding of the trajectories of planets and stars, most of the medieval rulers and elites were well versed in and aware of the different astronomical traditions. For example, the first Mughal ruler, Babar, was cognizant of some of the practical uses of astronomical tables. In his discussion of the astronomical work of one of his ancestors, Mirza Ulugh Beg of Samarkand, Babar described a "fine building [which] is an observatory, that is, an instrument for writing Astronomical Tables. [B]y its means the Mirza worked out the Kurkani Tables, now used all over the world." 185Another passage indicates that Babar was aware of other distinctive traditions of observational astronomy: "Not more than seven or eight observatories seem to have been constructed in the world. Mamum Khalifa made one with which the *Mamumi* Tables were written. Batalmus [Ptolemy] constructed another. Another was made, in Hindustan, in the time of Raja Vikramaditya Hindu in Ujjain and Dhar. The Hindus of Hindustan use the Tables of this Observatory."186Astronomical observation and the calendars compiled as a result of such observations were useful in the sphere of religion as well as in the administration of the empire. For example, in the construction of mosques in south Asia, particular care had to be taken to ensure that they were built in such a way that people praying faced Mecca. In Babar's time, astronomical observation was being utilized to achieve accuracy in delineating the ritually specified directional orientation of the Muslim places of worship. In 1498 A.D. Babar recorded in his diary that "there is great discrepancy between the *qibla* of this mosque and that of the College; that of the mosque seems to have been fixed by astronomical observation."187

Babar's son and successor, Humayun (15301536), was also keenly interested in and patronized astronomy. In Jahangir's memoirs, a reference is made to a handwritten manuscript by Humayun that contained "an introduction to the science of astronomy, and other marvelous things, most of which he had

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studied and carried into practice." 188Abul Fazl records that shortly before his death, Humayun was planning to construct a large astronomical observatory and had even acquired a number of astronomical instruments.189During the reign of his son, Akbar, (15361605), patronage of astronomy and astrology continued. Abul Fazl in his *Akbar Nama* mentions "Maulana Chand, the astrologer, who possessed great acuteness and thorough dexterity in the science of the astrolabe, in the scrutinizing of astronomical tables, the construction of almanacs and the interpretations of the stars."190This reference from Abul Fazl's account of Akbar's reign explicitly establishes a symbiotic relationship between astrology and observational astronomy. Maulana Chand compiled a set of astronomical tables known as *Tahsilat-i-Akbar Shahi*, which was referred to by the astronomer-statesman, Raja Jai Singh, almost two hundred years later. Finally, astronomy was explicitly patronized during the reign of Akbar's son, Jahangir (16051627), who was an accomplished naturalist himself.

His memoirs, the *Tuzuk-i-Jahangiri* contain extensive accounts of the flora and fauna of medieval India.191The following extract from Jahangir's memoirs illustrates his own keen interest in astronomical knowledge and provides evidence of the presence of astronomers in that period who were well versed in techniques of observation and measurement:

> On Saturday the 18th, the camp was at Ramgarh. For some nights before this there appeared, at three *gharis* before sunrise, in the atmosphere, a luminous vapour in the shape of a pillar. At each succeeding night it rose a *ghari* earlier. When it assumed its full form, it took the shape of a spear, thin at two ends, and thick in the middle. It was curved like a sickle, and had its back to the south, and its face to the north. It now showed itself a watch (*pahar*) before sunrise. Astronomers took its shape and size by the astrolabe, and ascertained that with differences of appearance it extended over twenty-four degrees. It moved in high heaven, but it had a movement of its own, differing from that of high heaven, for it was first in Scorpio and afterwards in Libra. Its declination (*harakat-i-arz*) was mainly southerly. Sixteen nights after this phenomenon, a star showed itself in the same quarter. Its head was luminous, and its tail was two or three yards long, but the tail was not luminous. It has now appeared for eight nights; when it disappears, the fact will be noticed, as well as the results of it.192

It is evident that due to a number of factors, astronomy attracted considerable patronage in medieval India. One of the factors that indirectly stimulated interest in astronomical observation was the widespread use of astrology for determining the auspicious as well as accurate timing for significant undertakings. Astronomy and astrology were not clearly demarcated from each other in the medieval or the ancient period, and the memoirs of the various Mughal rulers are replete with references that establish the significance accorded to the effect of the positions of the stars and constellations on human affairs. Thus Babar, while involved in a battle near Kabul in 1503, observed: "the reason I

was so eager to engage was that on the day of the battle, the Eight stars were between the two armies; they would have been in the enemy's rear for 13 or 14 days if the fight had been deferred." 193Three years later, riding in the vicinity of Kabul, he recorded, "I had been in these parts several times before; drawing inferences from those times, I took the Pole-star on my right shoulder blade, and *with some anxiety*, moved on."194In another march to Kabul in 1505, he noted: "I had never seen Suhail [Canopus]; when I came out of the pass, I saw a star, bright and low."195Finally, while touring the newly conquered territory of Hindustan, or India, he defined the position of the city of Chanderi near Agra, by noting: "In Chanderi the altitude of the pole star is 25 degrees."196These observations, recorded in Babar's memoirs, indicate both a concern with the possible influence of the position of stars on human action, as well as familiarity with observational and measurement techniques for accurately determining these positions.

The symbiotic relationship between astrology and astronomy and its significance in influencing some aspects of the administration of the Mughal empire continued under the rule of the later Mughals. Like Babar, Jahangir's memoirs are replete with observations like "the astrologers and astronomers chose the day of *Mubarak-shamba*, the 28th of the Divine month of Dai as the proper time at which to enter the capital of Agra,"197and "as the auspicious hour for entering the city had been fixed for the 14th, I halted here, and at the selected auspicious hour proceeded to the fort." 198 The concern with the influence of the position of stars is reflected in the determination of the exact timing of crucial celestial conjunctions, and each entry of Jahangir's memoirs is prefaced by observations like: "The transit of the sun into his house of Aries took place on Friday after 12 1/2 *gharis* or 5 sidereal hours,"199and "On Wednesday the 22nd *Zi-l-qada*, 1015 (March 10, 1607), when 3 1/2 *gharis* of the day had passed, the sun rose to his House of Honour."200These observations, recorded in the first decade of the seventeenth century continued to be expressed in the late eighteenth century, when, according to a handwritten manuscript from 1780, "the return of the World Enlightening Sun into the sign of Aries happens at 2 *Gurrys* and 3 *Puls* remaining of the latter part of the night."201Considering the importance attached to the pursuit of astrology and astronomy, it is not surprising that its practitioners were patronized by the Mughal rulers. Thus, Jahangir explicitly refers to "Lachin Munajjim, astrologer [who was provided with] 1,000 personnel and 500 horses"; to another astrologer, "Jotik Ray [who was] weighed against money [that] was given to him as a reward"; and to the provision of funds for "a brahman of the name of Rudar Bhattacharaj who was engaged at Benares in teaching [and] has studied well, both in the rational and traditional sciences, and is perfect in his own line."202

A final reason for the patronage of astronomy was its practical use in the compilation and reform of different systems of calendars, which relied on,

depending on the system adopted, solar or lunar observations. For example, in 1584, during the reign of Akbar, Fathullah Shiraz reinterpreted the astronomical data from the tables of the central Asian astronomer Ulugh Beg. As a result, a new and reformed solar Ilahi-era calendar was introduced and adopted as the official calendar of the Mughal empire for nearly seventy-five years. During Aurangzeb's reign in 1659, this solar calendar was replaced by the lunar Hejira calendar, 203which, in turn, was rejected after his death in 1708. Efforts at compiling a reformed solar calendar based on empirical observation of the trajectory of the sun led to the construction of the giant astronomical observatories by Jai Singh in early eighteenth-century India. Overall, regardless of the changing sociohistorical context, astrology and astronomy were patronized by successive rulers. In fact, the changing sociohistorical conditions were conducive to a partial synthesis of indigenous Indian, central and west Asian astronomical traditions.

The Astronomical Observatories of Raja Jai Singh

The synthesis of these diverse astronomical traditions found its most spectacular expression in the five gigantic observatories designed by Raja Jai Singh II, and completed between 1722 and 1739.204Jai Singh was a Rajput ruler who exercised control over a semi-autonomous territory in present-day Rajasthan. Although Jai Singh had control over this vast territory, he also owed nominal fealty to Muhammad Shah in Delhi, the emperor of a rapidly declining Mughal empire. Raja Jai Singh was a statesman-scholar who was well versed in astronomy, and patronized a large number of indigenous astronomers of his time. Patronage was a significant factor, as without the wealth from Jai Singh's treasury, neither the construction of these giant observatories nor the support for different schools of indigenous astronomers would have been possible in the late medieval period.

Constructed in five different citiesDelhi, Jaipur, Varanasi, Ujjain and Mathurathese masonry observatories, built of lime and stone, have attracted the attention of a range of observers through history. These range from Joseph Tieffenthaler, a Jesuit who in 1751 observed the Jaipur observatory and praised it for "both for its novelty and its liberal supply of astronomical instruments," describing it as "a clever piece of work, enabling the observer to find the sun's altitude at any moment of the day"205to modern historian of science Derek J. de Solla Price who took it to represent "a remarkable instance, from other times and another culture than our own, of heavy governmental expenditures."206

Of the five observatories built in Jai Singh's reign, only twoat Delhi and Jaipurhave survived in perfect condition, while others are in various states of ruin. These Indian observatories are unique because unlike similar structures built earlier in China, west Asia, and Europe, most, though not all,

of the instruments for observation are built not of metal, but of lime and stone, the significance of which will be discussed later. In addition to a number of conventional measuring devices like two seven-foot iron astrolabes, and a number of large masonry instruments such as the mural quadrants, meridian circles, and azimuth circles common to other observatories in Europe and west Asia, the Delhi and Jaipur observatories have three major, gigantic masonry devices, which were the ingenious inventions of Jai Singh and his team of astronomers. These are the *Jai Prakash* (the light of Jai), *Ram Yantra* (Rama's device, or instrument), and *Samrat Yantra* (device, or instrument, of the world).

The *Samrat Yantra* is a large right-angled triangle oriented along the local meridian. Its hypotenuse, or gnomon, is inclined to the horizontal at an angle equal to the local latitude and is thus parallel to the axis of the earth. Two graduated quadrants are attached to the base of the triangle and are oriented in such a way that taken together they form a semicircle centered upon the hypotenuse. These quadrants have radii of fifteen meters. The shadow of the gnomon as it sweeps along the quadrants indicates the azimuth of the sun as well as the solar time. Readings by contemporary astronomers indicate that a skilled observer could use this instrument to read solar time to a precision of fifteen seconds. 207The graduations on the hypotenuse of the *Samrat Yantra* enabled the measurement of solar altitude, an innovation that, according to contemporary astronomer William Blanpied, "appears to have been original with him."208In their observations, Jai Singh and his team of astronomers attached particular importance to the measurements of the daily and annual movement of the sun.

Consisting of a pair of hemispherical bowls about 4.2 meters in radii, the *Jai Prakash* (light of Jai) is the most ingenious and original of Jai Singh's inventions. The surfaces of these bowls are inscribed with the celestial coordinates and oriented so that the positions of celestial objects can be mapped directly onto them. Two straight wires in the horizontal plane, one oriented north and south and one east and west, intersect at what would be the center of the complete sphere. The celestial bodies would be mapped into the concave hemisphere by an observer inside the bowl who would observe them through the points of intersection. Nocturnal measurements were made by fixing one end of a taut string to the intersection of the two horizontal wires, with an observer at the bottom of the concave bowl who moved about until the free end of the string could be fixed at a point along which a particular star or planet could be sighted. The intersection of the string and coordinates inscribed on the hemisphere then gave the celestial coordinates of the planet or star. To facilitate such observations and measurements, passages with stairways were cut into the hemispheric bowls. Daytime measurements were simpler and easier to make. Since the parallel rays of the sun are equivalent to lines of sight, the shadow cast upon the concave hemisphere by the intersection of the two horizontal wires falls upon the inscribed lines, defining its celestial coordinates.

Finally, the *Ram Yantra* was devised for making both daytime and nocturnal measurements. It consists of a pair of large, complementary, open-topped cylinders with vertical columns at their centers. Both the inside walls and the floors of the instruments are graduated to permit measurements of altitudes and azimuth angles. The heights of the central columns and of the concentric, surrounding walls are equal to each other as well as to the radial distance from the outer circumference of the column to the inner circumference of the walls. This dimension is equal to about 8.4 meters at the Delhi observatory. At sunrise, the top of the column casts its shadow on the upper edge of the walls, and, later in the morning, when the tip of the shadow falls at the intersection of the walls and floor, the sun's azimuth is forty-five degrees. At any other time the tangent of the sun's azimuth angle follows from the length of its shadow on the floor or on the wall of the instrument, and the known height of the walls and the central column. Likewise, the sun's altitude is determined by noting the position of the column's shadow relative to the appropriate radial graduations on the floor and walls. 209

Overall, the observatories in the various cities contained a number of other conventional instruments, which have been described by a number of scholars.210Some commentators have suggested that giant masonry instruments were anachronisms in an age when more efficient and compact metallic instruments for observation were available. By the time Jai Singh's observatories were constructed, Newton had already published his *Principia*, which provided an understanding of the theoretical aspects of celestial mechanics; John Flamsteed had published his catalogue of stars at the Greenwich Observatory and the Copernican revolution had already legitimized a heliocentric cosmology.

However, such a view ignores the fact that Jai Singh had tried some metal instruments and found them wanting, at least as far as specific astronomical goals were concerned. In the preface to the elaborate astronomical table, or the *Zij Mohammad Shahi*, which Jai Singh had compiled on the basis of direct observations, he makes it clear that initially he had constructed and employed metal instruments for making observations, but they proved to be problematic because

> brass instruments did not come up to the ideas which he had formed of accuracy, because of the smallness of their size, the want of their division into minutes, the shaking and wearing of their axes, the displacements of the centres of the circles, and the shifting of the planes of the instruments. [He therefore constructed instruments] of stone and lime, of perfect stability, with attention to the rules of geometry, and adjustment to the meridian, and to the latitude of the place, and with care in the measuring and fixing of them; so that the inaccuracies from the shaking of the circles, and the wearing of their axes, and displacement of their centres, and the inequality of their minutes, might be corrected.211

An additional reason that led Jai Singh to reject the use of metal instruments was the hot climate of northern India. References to the inaccuracy of the brass instruments due to the "displacements of the centres of the circles and the shifting of the planes of the instruments" hint at the fact that under conditions where temperatures could touch forty-eight degrees Celsius in the summer, the expansion induced by the heat would have impaired the accuracy of such instruments.

It would seem then that certain "ecological" 212or environmental factors inhibited the widespread use of brass instruments for observational astronomy, which demands utmost accuracy and precision. Moreover, the precise goal of Jai Singh's astronomical pursuits provide further clues to his rejection of metallic instruments and his failure to use telescopes for making celestial observations.

Jai Singh's primary goal in building the observatories was to make solar observations specifically for the purpose of collecting astronomical data to reform the solar calendar in use during his time. His interest did not lie in measuring the position of fixed stars, but in devising new instruments for providing a continuous determination of solar time and for making repeated measurements of the length of the solar year.213This interest was partly rooted in the ancient Indian tradition of calendrical sciences, and partly in the importance, from a religious point of view, of the accurate prediction of eclipses. It is also evident from Jai Singh's preface to the *Zij Mohammad Shahi* that the collection of such lunar and solar data was also considered to be important for the administration of the declining Mughal empire in the reign of Muhammad Shah. Finally, Jai Singh's aim in building the observatories was to compile astronomical tables based on observation rather than calculation or computation. According to Jai Singh (who here refers to himself in the third person),

> He found that the calculation of the places of the stars as obtained from the tables in common use, such as the new tables of Seid Gorhaanee the Hindu books, and the European tables in many cases give them widely different from those determined by observation: especially the appearance of the new moons, the computation of which does not agree with observation. *Seeing that very important affairs both regarding religion and the administration of empire depend upon these; and that in the time of the rising and setting of the planets, and the seasons of eclipses of the sun and moon, many considerable disagreements, of a similar nature, were found*; he represented it to his majesty Mahommed Shah (emphasis added).214

In the same account by Jai Singh, the Mughal emperor Muhammad Shah's response is quoted as "having prepared all the apparatus of an observatory, do you so labour for the ascertaining of the point in question, that the disagreement between the calculated times of those phenomena, and the times in which they are observed to happen may be rectified?"215Jai Singh's emphasis on observational as opposed to purely calculational astronomy is further reflected in the introduction to another text where he states: "In the future,

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whoever be the lord of the realm, he should assure himself by making enquiries into the motions of the heavenly bodies by making instruments. Reliance should be placed on the results obtained by actual observation. For the true motion of the stars is one thing, that obtained by calculation from standard works another." 216Overall, the astronomical program of Jai Singh reflected the attempt to synthesize Indian, central and west Asian traditions of astronomy. In constructing giant instruments of masonry, Jai Singh was following the well-established tradition of medieval Islamic observatories represented among others by the observatory constructed by Ulugh Beg in 1428 A.D. at Samarkand in central Asia. In fact Jai Singh followed Ulugh Beg's astronomical tables while compiling his own tables, the *Zij Mohammad Shahi*. So although there was nothing new in the construction of masonry instruments per se, the specific instruments he constructed were distinctive in style, designed for the purpose of making distinctive measurements, which reflected the changing social and political context of his time. As mentioned earlier, one of these changes was the attempted switch from a lunar calendar to a solar one after the death of Aurangzeb. Such imperatives necessitated the construction of specific instruments and devices designed to keep track of the movement of the sun.

Although Jai Singh had a team of Indian astronomers to help him with his work, a significant feature of his astronomical project was the presence of European astronomers at his observatory. The presence of European astronomers is significant as it represented one of the last opportunities for a conscious cross-cultural scientific exchange between the indigenous and European scientific tradition before the consolidation of British colonialism. Partly due to his contact with the Portuguese Jesuits who were based in Jaipur, Jai Singh expressed considerable interest in the state of European astronomy. In fact his curiosity about European techniques of observation led him to finance an expedition of some of his court astronomers to Portugal. The astronomers who visited Portugal brought back the astronomical tables of LaHire with them. After examining LaHire's tables, Jai Singh claimed to have detected a number of errors and discrepancies in them. According to Jai Singh's account:

> After seven years had been spent in this employment, information was received, that about this time observatories

had been constructed in Europe, and that the learned of that country [sic] were employed in the prosecution of this important work. For this reason, having sent to that country several skilful persons along with Padre Manuel, and having procured the new tables which had been constructed there thirty years before, and published under the name of Leyyer [LaHire], as well as the European tables anterior to those; on examining and comparing the calculation of these tables, with actual observation, it appeared there was an error in the former, in assigning the moon's place, of half a degree. [S]ince in Europe, astronomical

instruments have not been constructed of such a size, and so large diameters, the motions which have been observed with them may have deviated a little from the truth. 217

Jai Singh attempted to comprehend the sources of these "errors" and "discrepancies" by corresponding with a French Jesuit astronomer, Claude Boudier, who was based at the French station of Chandernagore. According to Boudier, Jai Singh raised detailed questions about European observational techniques, including "a few questions which I [Boudier] was not equipped to answer at the time."218As a result of their correspondence, Boudier was invited by Jai Singh to the city of Jaipur in early 1734.

The contact with Claude Boudier and the mission of Indian astronomers to Portugal promised some cross-cultural titration of scientific ideas. However, such an exchange did not occur partly because Jai Singh found that European observational techniques and astronomical tables were not very relevant to his primary goal of obtaining solar, lunar, and planetary data. Insofar as Jai Singh's astronomical program did not aim at measuring the position of fixed stars, he found that he had little to learn from new developments in astronomy in Europe, especially so in view of the discrepancies he had detected. It should be also noted that, despite the presence of Jesuit astronomers, there is no evidence that Jai Singh was aware of the Copernican revolution. Overall the work of Jai Singh and his team of astronomers was located within the geocentric worldview and was unaffected by the Copernican revolution in Europe mainly because the goals of Indian astronomical endeavors were quite different. In any case, the astronomical tables compiled by Jai Singh and his associates were used in India throughout the eighteenth century and were considered the best available. The flyleaf of the British Museum's copy of Jai Singh's table contains the handwritten English comment, "by these tables eclipses are calculated and Almanacks composed in the northern provinces of India to this day."219There is further evidence that the astronomical tables of Jai Singh continued to be used in Bengal, a thousand miles from his principality, almost forty years after his death.220

On the whole, Jai Singh's astronomical program can be judged as anachronistic, only if the judgment is based on a comparison with the precision in astronomical measurement achieved years earlier by John Flamsteed at Greenwich. However, judged in terms of his overall goal of collecting precise solar and lunar data for refining a calendrical system whose basis was well known, his work and his instruments remain unique in the annals of Indian astronomy. Finally, Jai Singh was one of the very few precolonial Indian astronomers who made a serious attempt to understand European astronomy. Overall, the observatories and the detailed astronomical table prepared by Jai Singh epitomized the skillful combination of science and technology in precolonial medieval India. Even as Jai Singh and his team of Indian astronomers

were making observations and preparing tables, the chain of events that was later to culminate in the consolidation of British colonial rule, was unfolding in the coastal areas of India. However, before considering the complex social processes that culminated in the consolidation of British colonial rule in India, some tentative theoretical generalizations, based on the largely descriptive account presented above, are offered in the next section.

Science, Technology, and Patronage in Ancient and Medieval India

In accounting for the development of modern science and technology in seventeenth-century England, Robert K. Merton drew on Max Weber to emphasize the crucial role of the antimagical cosmology of Protestantism. 221This process of demagification and rationalization contributed to a transformation of the image of God as the creator to the Divine

Mechanic. With this interpretation, the ascendancy of Protestant religious values encouraged the early scientists and members of the Royal Society to search for God in the immutable laws of nature. Although Weber himself did not invoke a disembodied "Protestant ethic" as the exclusive causal factor responsible for the development of modern rational science and capitalism,222and, indeed, Merton himself considered the role of a number of structural and material factors in his analysis, a number of scholars, including I. Thorner and Joseph Ben-David, have overstated the role of Protestantism in providing crucial cultural support for the development of rational science by precipating "affective neutrality."223Some of these scholars have relied on a particular interpretation by Weber to emphasize a set of values or norms that provided a suitable social environment for innovations in the sphere of science and technology. However, such a one-sided emphasis on a particular set of values ignores the fact that Weber's comparative and historical sociology focused on social structures rather than on disembodied values or belief systems.224As a number of scholars have pointed out, despite the dominant Parsonian gloss on Weber's ideas, in accounting for the origins of modern science and its connection to capitalism, Weber's analysis of the emerging process of rationalization involved a sophisticated consideration of highly contingent historical, structural, and material factors.225Indeed Weber's richly textured analysis and subtleties of method are only recently begining to emerge after decades of oversimplification by earlier North American interpreters.

In a recent appraisal of the relevance of Max Weber to the sociology of science and technology, Bryan Turner has rightly pointed out that an excessive focus on Protestantism as the main cultural support for the development of modern science lends itself to yet another "uniqueness of the West" argument.226Drawing on the work of Joseph Needham and other scholars, Turner

has demonstrated that such an interpretation, like many other theoretical abstractions, is flawed and does not stand up to careful historical scrutiny. Thus the contention that all "Oriental" societies are characterized by a series of absent featuresprivate property, democratic rights, rational law, the city, and natural scienceis open to objections on purely empirical grounds. There is, however, as Turner points out, a major theoretical problem in the identification of a rational cosmology as a precondition for any scientific and technological endeavor. 227Such a theoretical perspective does not account for the presence of substantial theoretical and empirical advances in science and technology in a number of civilizations where such rational cosmologies were not necessarily hegemonic.

As the monumental work of Needham has indicated, magic, divination, and science were symbiotically interconnected in ancient and medieval Chinese society, and the situation was not radically different in medieval Europe.228As should be evident from the discussion in the last two chapters, a similar relationship obtained both in ancient and medieval India. In ancient India, certain religious and ritualistic imperatives had the unintended consequence of stimulating a number of innovations in geometry and mathematics. In both ancient and medieval India, a number of social and religious factors led to interest in and patronage of astrology, dismissed by James Mill as "one of the most irrational of all imaginable pursuits,"229which, in turn, provided extensive support for a number of developments in mathematics, trigonometry, and observational astronomy. Similarly, as Lynn White Jr. has argued, the cosmology and "belief in the cyclical and self-renewing nature of all things"230prompted a search for a *perpetuum mobile* in twelfth-century India, an idea that, under the appropriate social conditions, may have contributed to the conceptualization of power technology in Europe. The same argument applies in the case of the development of the concept of "zero," which was inspired by the Indian cosmology of *Sunyata* and revolutionized mathematics, science, and technology. Finally, rational and empirical procedures in medicine and surgery in ancient India was literally developed on the margins of society by oppositional, heterodox movements of Buddhists, Jains, and Ajivakas. Overall, under specific and appropriate social conditions, certain social movements and cosmologies, which might be labeled mystical, otherworldly, and irrational, stimulated the emergence and development of a diverse range of scientific and technological innovation in ancient and medieval India.

However the argument above should not be read as support for the equally culturally determinist and sociologically redundant "uniqueness (and superiority) of the East" perspective, which has emerged recently. While some aspects of Indian religious doctrines and worldviews were conducive to innovations in science and technology, such factors cannot be considered in isolation from the contingent historical and socioeconomic circumstances constituting the wider social and structural context for the development of science and technology.

Thus, although the evolution of the concept of zero was stimulated by a specific religious cosmology, its use in the numeral system and in mathematical computation was simultaneously stimulated by and found ready application in thriving internal and international trade, commerce, and banking. And it was this flourishing international trade and commerce that facilitated the transmission of the Indian numeral system to Europe through the agency of Arab merchants.

In addition to the vigorous trade and commerce stimulating developments in mathematics, patronage of a stratum of intellectual workers constituted another significant factor in the periodic waxing and waning of scientific and technical innovation in precolonial India. While analyzing the patterns of scientific development in "traditional societies," Bryan Turner has argued that "one general requirement for the development of any sustained, especially institutionalized, scientific activity is the presence of an economic surplus in the hands of the state, merchants or nobles which can be distributed to patronise a scientific or intellectual stratum." 231Although Turner arrives at this general formulation through an examination of scientific and technical innovation in west Asian societies, his argument is quite relevant to the case of ancient and medieval India, too. As should be evident from the detailed discussion above, the extension of patronage by the state, whether for large-scale irrigation projects or gigantic astronomical observatories of Jai Singh, constituted an essential factor in sustaining and promoting scientific and technical innovation. In fact, in the case of astronomy in late medieval India, Jai Singh epitomized a rare combination of statesman and scientist, which enabled him to take direct interest in astronomy, provide funds from his treasury for the construction of observatories in five cities, and to hire and sustain large teams of Indian and some European astronomers to work in his various observatories.

Thus, whether the political system and social structure of precolonial India is characterized by Marx's "Asiatic mode of production," Weber's "patrimonial bureaucracy," or Needham's "bureaucratic feudalism" (a term used for Chinese society), there is no doubt about the existence of strong, centralized, political authority in various periods of Indian history. Contrary to the arguments of those who have stressed a laissez-faire model for the advancement of science, where the independent, individual scientist accumulates knowledge free from any encroachment from the state, in the case of precolonial India, scientific activity usually flourished in periods when relatively strong and centralized state systems and empires accumulated enough surplus to patronize scientists, technicians, and scholars. This is not to claim that all scientific activity was necessarily completely dependant on state patronage or that there were no self-supporting individuals who engaged in such intellectual pursuits. The point Turner makes that is relevant for the argument being advanced here is that economic surplus, either in the hands of independent nobles and merchants or dispensed through a system of state patronage, constituted an essential requirement for "sustained and institutionalized" scientific

activity. Although the role of cultural, religious, and ideological factors is no doubt important, another crucial requirement for the production of scientific and technical knowledge was the accumulation and control of economic surplus by states, which could support strata of religious specialists, scientists, and technicians. This was true for a diverse range of periods in Indian history, from the relatively recent Mughal empire and the earlier Mauryan empire to the earliest era of the Indus Valley civilization. Although it is not possible to reconstruct the finer details of the system of political authority in the Indus Valley, extensive archaeological excavations make clear the sheer scale and complexity of the civilization. In the words of Bridget and Raymond Allchin, the system of political authority of the Indus Valley "represented a special achievement in the world of the third millenium B.C. a time when in other parts of world the largest effective unit was little more than a city state." 232In any case, the decline or "collapse" of the Mughal empire, precipitated by internal structural contradictions and accelerated by the growth of trade by the East India Company, led to the decline and eventual disappearance of patronage for scientific activity or large-scale public works projects, which had encouraged technical innovation.

The focus on the articulation of structural, material, and cultural factors in the development of scientific thinking in India also highlights the problems associated with narratives that depict an unbroken line of development of science and technology in ancient "Hindu" India, which was presumably completely disrupted with the arrival of "Muslim" rule in the medieval period. Such narratives, deriving from a multiplicity of sources and spurred by diverse ideological interests and motivations, do not stand up to sociological and historical scrutiny. The motives of the Hindu chauvinists and bigoted ideologues of the *Hindutva* movement are, of course, quite transparent, but their idea of a "Hindu" science, like the recent movement for the revival of "Islamic" science in other parts of the world,233which relies on the mobilization of emotions and passions by focusing on resentment and an extremely culturalist reading of the past, is untenable. From a

quite different perspective, the vigorous and spirited defense of "traditional" science, technology, and worldviews as superior to counterparts spawned by "modernity" is fraught with similar problems. The final chapter will discuss the second narrative, made popular by Vandana Shiva, Claude Alvares, Ashis Nandy, Susantha Goonatilake among others, and its reliance on a selective reordering of the past in order to construct an idealized view of precolonial society. It presents a continuous and uninterrupted legacy of "traditional" science and technology, which apparently coexisted in perfect ecological harmony until the disruption effected by colonialism. A more grounded sociohistorical investigation, as attempted here, does not deny the presence of rich and diverse traditions of science and technology at various points in Indian history, but attempts to understand and interpret the structural factors that sustained uneven and by no means uninterrupted periods of innovative scientific and technological activity.

Although these issues will be explored later in further detail, suffice it to point out the inadequacy of an idealized and romanticized picture of harmonious, "eco-friendly" science and technology in a hermetically sealed "traditional" precolonial India.

Joseph Needham's work has demonstrated that the legacy of the Chinese contribution to science and technology is an impressive one. It includes the invention of gunpowder, the magnetic compass, the stirrup and harness for horses, paper making, the stern-post rudder, the wheelbarrow, and a number of contributions in the field of mathematics and astronomy. 234A similar list of Indian contributions would include: trigonometry, the concept of sines, the concept of zero and the modern numeral system, the concept of power technology, the cotton gin, the "parallel worm" rolling mill, the toe stirrup, the *noria*, the drill plough, and crucible-cast steel. As evident by the discussion in the last two chapters, precolonial India was hardly a tabula rasa in the field of science and technology, as depicted by James Mill in his *History of British India*. However, the narrative and rhetoric of Mill, Grant, and Macaulay should be located within the wider context of the exercise of colonial power and of their positions at various levels of the colonial administration. Given the fact that most of the evidence for the reconstruction of science and technology in the late medieval period comes from the accounts of early European and European observers, it is unlikely that Mill, Macaulay, or Grant were totally unacquainted with these writings. In retrospect, their views represent responses to specific issues relating to colonial administration, in a period when machines had become the "measure of men," and when the dominant discourse of India, bereft of any science and technology, provided the ideological justification for specific colonial policies as well as for the Raj in general. The social processes at work in the consolidation of the British Empire in India, the introduction and role of modern Western science and technology in colonial India, and the response of Indians to the introduction of modern science under British colonial rule are examined in the chapters that follow.

Notes

1. John Huyghen van Lichschoten, 1885: 230.

2. Francois Bernier, 1968: 338.

3. Letter from Dr. Helenus Scott to Joseph Banks, dated January 19, 1972, reprinted in Dharampal, 1971: 268.

4. J. Z. Holwell, 1971: 146.

5. J. Campbell, 1971 [1842]: 26062.

6. J. Stodart, 1818: 57071.

7. Irfan Habib, 1979; for a comprehensive analysis of the economy of the Mughal empire, see Shireen Moosvi, 1987.

8. Simon Digby, 1982.

9. K. N. Chaudhuri, 1990: 318.

10. There is a large volume of literature on this issue. The question of why the technological revolution occurred in the cotton textile industry and not in any other sector is discussed by David Landes, 1969.

11. Cited in Romila Thapar, 1974: 60.

12. Herodotus, quoted in D. Schlingoff, 1974: 81.

13. Cited in Schlingoff, 1974: 81.

14. H. Gerth and C. W. Milla, eds., 1964: 123.

15. R. Shamasastry, 1960.

16. Cited in Schlingoff, 1974: 82. Further details of the social organization of the manufacture of cotton can be found in Thapar, 1959: 6568.

17. Neil Cowell, ed., 1886: 82.

18. Schlingoff, 1974: 89.

19. *Ibid.*, 86.

20. Quoted in Habib, 1970: 142.

21. K. N. Chaudhuri, 1974: 177.

22. Habib, 190: 6.

23. *Ibid.*, 7.

24. Vijaya Ramaswamy, 1980: 22728.

25. Joseph Needham, vol. 4, 1954: 122. Habib (1970: 147) also believes that the "wooden-gin could quite possibly have originated in India."

26. R. J. Forbes, vol, 4, 1956: 155.

27. L. White (1960) has subjected the issue of the Indian origins of the spinning wheel to a detailed scrutiny and found that its presence in ancient India is entirely undocumented.

28. Quoted in K. N. Chaudhuri, 1990: 316.

29. Habib, 1970: 143.

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30. Wilhelm Rau, cited in Ramaswamy (1980: 22930), quotes the following verse from the *Atharvaveda*, which definitely refers to the vertical loom: "A man weaves it, ties it up; a man hath borne it upon the firmament. These pegs propped up the sky; chants they made shuttles for weaving."

31. K. N. Chaudhuri, 1990: 31516. Further details can also be found in Habib, 1976: 18192.

32. Ramaswamy, 1980: 232.

33. Habib, 1980: 8.

34. A detailed early seventeenth-century traveler's account of the cultivation and production of indigo for purposes of preparing different kinds of dyes in India can be found in Francisco Pelsaert, 1972 [1628]: 1018. Further details of processes involved in the dyeing and finishing of cotton textiles can be found in the appendix to William Robertson, 1809: 22930; 37273. Comprehensive accounts of the products as well as the process of dyeing in ancient and medieval

India can be found in Mira Roy, 1978 and H. K. Naqvi, 1991.

35. K. N. Chaudhuri, 1990: 317.

36. Habib, 1980: 89.

37. Ramaswamy, 1980: 23435.

38. Jean Baptiste Tavernier, 1905 [1677]: 30203.

39. Tavernier, 1905: 302.

40. I rely on K. N. Chaudhuri, 1974: 14750.

41. Edward Baines, 1835: 74.

42. Baines, 1835: 75.

43. James Mill, vol. 2, 1840: 16, 21.

44. Mill, vol. 2, 1840: 17.

45. Robert Orme, quoted in Mill, 1840: 17.

46. K. N. Chaudhuri, 1978: 275.

47. Habib, 1980: 9.

48. Helenus Scott, 1971: 26465.

49. Scott, 1971: 264.

50. *Ibid.*, 26970.

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51. Habib, 1980: 710. See Tapan Raychaudhuri, 1982: 29293.

52. Annette S. Beveridge, 1970 [1922]: 520.

53. Pelsaert, 1970 [1925]: 60.

54. Francis Buchanan, 1807: 41/

55. Tavernier, 1905 [1677]: 304.

56. Baines, 1835: 57.

57. F. R. Allchin, 1962: 195211; K. T. M. Hegde, 1981: 189201; S. D. Singh, 1962: 21216; D. D. Kosambi, 1963: 30918; Dilip K. Chakrabarti, 1977: 16684; Amita Ray and Dilip K. Chakrabarti, 1975: 21932.

58. F. R. Allchin, 1962: 201.

59. *Ibid.*, 202.

60. *Ibid.*

61. *Ibid.*, 203.

62. *Ibid.*, 207.

63. R. Allchin and B. Allchin, 1982; Dilip K. Chakrabarti, 1977: 16684.

64. V. A. Smith, 1987: 118.

65. Valentine Ball, 1881: 338.

66. W. E. Clark, 1962: 33839.

67. H. S. Jarett, 1949: 192.

68. *Ibid.*, 273.

69. Habib, 1980: 23.

70. K. N. Chaudhuri, 1990: 325.

71. C. E. Smith and R. J. Forbes, 1957: 35.

72. Scott, 1971: 271. Other early accounts of the process of steel manufacture in India include: George Pearson, 1795; J. Stodart, 1818.

73. Stodart, 1818: 57071.

74. *Ibid.*, 570.

75. *Ibid.*

76. K. N. Chaudhuri, 1990: 330.

77. Alexander Hamilton, 1930: 217.

78. These accounts include: Benjamin Heyne, 1795; James Franklin, 1829; J. Campbell, 1842. All of these accounts are reprinted in Dharampal, 1971.

79. Franklin, 1971: 248.

80. Campbell, 1971: 26062.

81. Habib, 1980: 16.

82. A detailed examination of the evidence for the existence of firearms prior to the fifteenth century can be found in Iqtidar Alam Kahn, 1981.

83. *Ain-i-Akbari*, vol. 1, 125. Cited in Habib, 1980.

84. Habib, 1980: 17.

85. The process of manufacture is described in the *Ain-i-Akbari*, vol. 1, 125. Cited in Habib, 1980: 18.

86. Bernier, 1968: 254.

87. *Ibid.*, 217.

88. *Ibid.*, 21718.

89. *Ibid.*, 218.

90. Habib, 1980: 19; William Irvine, 1962.

91. K. N. Chaudhuri, 1990: 32728.

92. Pietro della Valle, 1973 [1891]: 147.

93. Needham, 1969: 6668.

94. Frank H. Winter, 1974: 361.

95. *Ibid.*, 36162.

96. Bernier, 1968: 48.

97. Niccolao Manucci, 1907: 276.

98. William Foster, 1921: 279.

99. Winter, 1974: 362.

100. *Ibid.*, 363.

101. *Ibid.*

102. *Ibid.*

103. *Ibid.*

104. Lynn White, 1962: 38.

105. Needham, 1969: 87.

106. White, 1962: 15. See also Needham, 1969: 8687.

107. White, 1962: 14.

108. *Ibid.*, 11.

109. *Ibid.*, 15.

110. This account has relied heavily on Habib, 1970: 15859.

111. White, 1962: 15.

112. *Ibid.*, 19.

113. Hugh Murray, vol. 2, 1820: 23031.

114. Henry M. Elliot, vol. 1, 1869: 341.

115. B. Fuller, 1988 [1910]: 149.

116. William Tennant, vol. 2, 1804: 78.

117. Elliot, vol. 2, 1869: 34041.

118. Alexander Walker, 1971 [1820]: 18186.

119. Thos. Halcott, 1971: 209.

120. Elliot, vol. 2, 1869: 342.

121. Halcott, 1971: 210.

122. *Ibid.*

123. *Ibid.*

124. *Ibid.*, 21113.

125. Dharampal, 1971: 213.

126. Needham, vol. 4, 19531959: 204; Needham's conclusions are based on the research of N. Deerr, 1940 and 1949.

127. S. N. Sen, ed., 1949: 169.

128. Habib, 1979: 155.

129. Elliot, 1869: 342; Walker, 1971: 196, 203.

130. Walker, 1971: 186.

131. Habib, 1963: 26.

132. Walker, 1971: 187.

133. Bryan Turner, 1978.

134. Habib, 1979: 159.

135. Gazetteer of the Bombay Presidency, 22 (Dharwar) (Bombay, 1884), 261. Cited in Habib, 1979: 15960.

136. Thapar, 1974: 325.

137. Issac Pyke, 1747: 167.

138. Scott, 1971 [1792]: 267.

139. Habib, 1963: 28 n. 24.

140. D. D. Kosambi, 1975 [1956]: 302.

141. Iqtidar Husain Siddiqui, 1986: 59.

142. I. H. Siddiqui, 1986: 59. See also Tatsuro Yamamaoto, M. Ara, and T. T. Kinowa, 1970.

143. Habib, 1963: 28. Further details of the system of irrigation in the Rajasthan area can be found in B. D. Chattopadhyaya, 1973: 298316.

144. *Ain-I-Akbari*, vol. 2, 135.

145. Tavernier, 1905 [1677]: 122.

146. Siddiqui, 1986: 71.

147. *Ibid.*

148. Diya U'ddin Barani, 1862: 567.

149. I. H. Siddiqui, 1986: 73.

150. *Ibid.*, 7576.

151. *Ibid.*, 75.

152. Habib, 1963: 3132.

153. William Francklin, 1798: 208.

154. Cited in Habib (1963: 34) from a *parwana* in the *Nigarnama-i Munshi* preserved at the Bodelian Library of Oxford University.

155. Habib, 1963: 28.

156. I. H. Siddiqui, 1986: 66 n. 51.

157. *Ibid.*, 65.

158. *Ibid.*, 6566.

159. *Babur-Nama*, trans. A. Beveridge, 1970: 486.

160. A. L. Basham, 1967: 184.

161. Needham, vol. 4, 19531959: 361.

162. Habib, 1970: 149.

163. Needham, vol. 4, 19531959: 361.

164. Ibid., 362.

165. John Fryer, vol. 2, 1967 [1912]: 94.

166. Habib, 1970: 15455.

167. N. Gangadharan, 1982: 15463.

168. Tazimuddin Siddiqi, 1980: 1824.

169. T. Siddiqi, 1980: 2021; The manuscript *Majmu'-i Diya'i* is preserved in the library of the Institute of History of Medicine and Medical Research at Tughlaqabad, New Delhi.

170. T. Siddiqi, 1980: 22.

171. A list of other treatises composed in the early medieval period can be found in I. H. Siddiqui, 1986.

172. Bernier, 1968: 338.

173. Colonel Kyd, quoted in Dharampal, 1971: xliii.

174. Scott, 1971: 268.

175. *Ibid.*, 271.

176. Ro. Coult, 1971: 14142; J. Z. Holwell, 1971: 14363.

177. Coult, 1971: 141.

178. Holwell, 1971: 14647.

179. *Ibid.*, 15051.

180. *Ibid.*, 153.

181. *Ibid.*, 15657.

182. *Ibid.*, 153.

183. John Huyghen van Lichschoten, vol. 1, 1885: 230.

184. According to one account of the inoculators, "the Operator takes his fee, which from the poor is a pound of cowries, equal to about a penny

sterling, and goes on to another door, down one side of the street and up on the other, and is thus employed from morning until night, inoculation sometimes eight or ten in a house" in Holwell, 1971: 152.

185. *Babur-Nama*, 79.

186. *Ibid.*

187. *Ibid.*

188. Henry Beveridge, ed., vol. 2, 1914: 82.

189. Henry Beveridge, trans., vol. 2, 1907: 361.

190. *The Akbar Nama of Abu-l-Fazl*, Henry Beveridge, trans., vol. 1, 1907: 69.

191. Jahangir also hired an artist and miniaturist, Mansur, to draw some of the birds he described in his memoirs. William A. Blanpied (1975: 114) has described the artist Mansur as "a sort of Indian precursor of Audubon." Extracts of Jahangir's accounts of the flora and fauna of medieval India can be found in M. A. Alvi and A. Rahman (1968).

192. Henry Beveridge, vol. 2, 1914: 48.

193: *Babur-Nama*: 139.

194. *Ibid.*, 323.

195. *Ibid.*, 195.

196. *Ibid.*, 597.

197. Henry Beveridge, 1914: 65.

198. *Ibid.*, 197.

199. *Ibid.*, 130.

200. Henry Beveridge, vol. 1, 1914: 85.

201. Cited in Blanpied, 1974: 108.

202. Henry Beveridge, vol. 1, 1914: 20304.

203. Blanpied, 1974: 106.

204. Unless otherwise indicated, I rely on Blanpied, 1974: 87126 for this section.

205. Severin Noti, 1906: 87.

206. Derek J. de Solla Price, 1964: 90.

207. Blanpied, 1975; The results of a recent testing of the accuracy of a whole range of instruments at Delhi and Jaipur can be found in V. N. Sharma and A. K. Mehra, 1991.

208. Blanpied, 1974: 98.

209. *Ibid.*, 99100.

210. V. N. Sharma and A. K. Mahra, 1991; A. Rahman, 1987; V. N. Sharma, 1982; 1991.

211. Jai Singh's preface to the *Zij Mohammad Shahi* in William Hunter, 1799. Hunter has translated Jai Singh's preface from the Persian, and the full text is reproduced in this article.

212. For a discussion of the ecological factors in the development of science and technology, please see Herbert H. Karp and Sal P. Restivo, "Ecological Factors in the Emergence of Modern Science," in S. Restivo and C. K. Vanderpool, 1974.

213. Blanpied, 1974: 10102.

214. Hunter, 1799: 18182.

215. *Ibid.*, 183.

216. Cited in Arthur Garett, 1902: 21.

217. From Jai Singh's preface to the *Zij*, in Hunter, 1799: 18788.

218. Claude Boudier, cited in Blanpied, 1974: 119.

219. Blanpied, 1974: 107.

220. *Ibid.*, 108.

221. Robert K. Merton, 1970.

222. Irving Zeitlin, 1994; Randall Collins, 1980; Weber, 1950.

223. Bryan S. Turner, 1987: 56. These scholars include I Thorner (19521953) and Joseph Ben-David, 1965.

224. Turner, 1987: 21.

225. *Ibid.*

226. *Ibid.*, 4.

227. *Ibid.*, 7.

228. Frances Yates, 1964; Uberoi, 1984.

229. Mill, vol. 2, 1840: 150.

230. White, 1960: 52223.

231. Turner, 1987: 13.

232. B. Allchin and R. Allchin, 1982: 22324.

233. Vasant Kaiwar, 1994.

234. Needham, 1969.

4
The Origins of British Colonial Rule in India

If a reform is in truth intended, where must it begin? And how am I to restore the simplicity of ancient times? How shall we reform the taste for dress? How are we to deal with the peculiar articles of feminine vanity which drains the empire of its wealth, and sends in exchange for baubles, the money of the Commonwealth to foreign nations, and even to the enemies of Rome?
Emperor Tiberius to the Roman Senate 1

Our ladyes all were set a gadding,
After these toys they ran a madding;
And nothing then would please their fancies,
Nor dolls, nor joans, nor wanton nancies,
Unless it be of Indian making.
Prince Butlers Tale (1696)2

Whilst they promote what Indians make,
The Employment they from the English take,
Then how shall Tenants pay their Rent,
When trade and coin (are) to India sent?

How shall folks live, and Taxes pay,
When Poor want work, and go away?
Such cargoes as these ships bring over
In England were never seen before.
England's Almanac (1700) 3

They're so Callico wise,
Their own Growth they despise,
And without an enquiry, "Who
Made 'em?"

Cloath the Rich and the Poor,
The Chaste and the Whore,
And the Beggar's a Callico
Madam.
O! this Draggle-tail Callico
Madam.
The Weaver's Complaint against the Callico Madams (1719)4

Early Encounters: Merchant-Travelers at the Mughal Courts

On January 10, 1616, Thomas Roe, in the role of an ambassador of the East India Company and bearing a letter from King James I, presented himself at the *darbar*, or the imperial court, of the Mughal emperor Jahangir. Roe was not the first English person to be granted audience at the Mughal imperial court. A number of English and European travelers

had visited and held appointments in various capacities in the service of the Mughal emperors.5More prominent among these were the Portuguese Jesuits at the court of Akbar and Jahangir. One of these was Father Monserrate who was appointed tutor to Prince Muradat by Akbar during 15801582, and who accompanied the emperor on his military campaign to Kabul.6Then there was Ralph Fitch who was one the first English travelers to have written an account of his travels in Mughal India between 1583 and 1591. Fitch and his party of merchant-travelers were sent out at the initiative of the English merchants who were organized under the name Merchant Adventurers. The purpose of the trip was to explore prospects for trade, and it was financed by the Turkey, or the Levant, Company7After a number of adventures, including imprisonment by the Portuguese in Goa, Fitch and his team, armed with a letter of introduction

from Queen Elizabeth to the Mughal emperor Akbar, managed to enter the territory of the Mughal empire. The letter from Elizabeth was never delivered, and Fitch spent spent most of his time exploring the eastern parts of India and parts of Southeast Asia, before returning to London in 1591. 8During his eight years of travels in India and Southeast Asia, Fitch9had accumulated a wealth of information about the region, especially about the resources and trading practices of the area, which were published in his *Principall Navigations* (15981600). A few years later, John Mildenhall, another trader working for the Levant Company appeared at the court of Akbar and requested permission for access to the trade of India. The Portuguese missionaries cautioned the ruler that the English were "all theeves" and under the pretence of being peaceful traders, would soon seize some of the emperor's ports.10Eventually certain concessions were granted to Mildenhall on the understanding that Elizabeth would send an ambassador to reside at Akbar's court.

The Mission of the East India Company

The East India Company, which had not sponsored Mildenhall's mission to the Mughal court, disputed the authenticity of the concessions he had obtained and decided to dispatch a number of its own ships on a similar mission. William Hawkins, the captain of one of these ships, was instructed to visit the capital city of Agra to solicit trading privileges from the Mughal emperor. Hawkins carried a letter from King James to the emperor and upon meeting with the latter, was granted some concessions on the understanding that he would remain at the court as an ambassador. A number of factors, such as serious concerns expressed by the merchants of the province of Gujarat, "Portuguese intrigues," and "his own indiscretions" forced Hawkins to quit the court and seek refuge on board a fleet that had arrived at Surat, the major city and trading center on the West coast.11This new fleet had arrived under the command of Henry Middleton who unsuccessfully attempted to establish the first English "factory" in the coastal city and trading center of Surat. Middleton retaliated by withdrawing his fleet to the Red Sea and holding a number of Indian ships from Gujarat for ransom, which was eventually paid.

Just a few months after this episode, Thomas Best landed at Surat with another fleet. The reception accorded to him was quite different, and subsequent negotiations with the local authorities led to the establishment of the first English "factory" at Surat in 1612. The Portuguese, who, in the wake of Vasco da Gama's landing in India in 1498, had established maritime dominance in the region and were well settled as merchants and traders on the southwest coast, did not take kindly to this first English establishment. A squadron was dispatched to engage the English ships in the hope of putting a decisive end to a new competitor and rival. The result of the engagement however turned out to

be quite the opposite of what the Portuguese had expected. A victory for the English contingent enabled Thomas Best to leave behind the "factory" in a state of relative security.

Soon after, a number of attempts were made to establish connections with the imperial court in the capital city of Agra. Thus Paul Canning, Thomas Kerridge, and William Edwards, all carrying gifts and letters from King James unsuccessfully attempted to gain favor with the Mughal emperor. Apparently, they were perceived as no more than merchants and, as a result, none of them were taken seriously at the imperial court. In December 1614, William Edwards wrote to the Governor of the East India Company that "the necessity of residence with the King is such as cannot bee avoyded; and hee to bee a man sent immediately from our King, for that the title of a merchant is of them much despised." Another merchant reflecting on the experience of William Edwards wrote that he must pretend to be an

ambassador, "for he which shall hold correspondancy with the Kinge muste be suche a one and no merchante (unless covertlye), for their pride is suche that they scorne them, making no more reaconing of them than of banyans, whome they hold little better then slaves." 12Just a few months earlier, another emissary of the East India Company, William Hawkins in his attempt to solicit a reply from Emperor Jahangir to King James's letter had been rebuffed by a noble who responded that "it was not the custome of so great a Monarch, to write in the kind of a Letter, unto a pettie Prince, or Governer."13

The Embassy of Thomas Roe: Concessions from the Mughals

It is in the context of these earlier unsuccessful attempts of the English merchants that the embassy of Thomas Roe assumes significance. Roe was selected by the directors of the East India Company amidst growing apprehension that the Portuguese control of the maritime trade routes and the presence of Jesuits at the Mughal courts might effectively stifle the promise of trade between England and India. In fact at the time of Thomas Roe's arrival at the port city of Surat, the English were on the verge of being expelled from their tenuous foothold in the Mughal dominions. According to William Forster, one of the Mughal princes, apparently influenced by the "advocates of the Portuguese" had already issued a *farman* (imperial decree) stipulating that "the English should dischardge one ship and have a monthes staye in trade, but no residences in the towne."14The directors of the East India Company, or the "Committees," as they were known, wanted somebody more than a merchant, an ambassador who could represent King James and the interests of the East India Company at the court of Jahangir. A majority of the "Committee"

of the East India Company agreed that "there is noe such necessitie of a marchannt there, butt rather of one that hath beene practisde in State buysines to reside att Agra to prevent any plotts that may be wrought by the Jesuits to circumvent our trade." 15

Although Thomas Roe was eventually able to procure an agreement with the Mughals regarding trading activities on the west coast of India, it was anything but a smooth process, and the outcome was far from certain. Two years after his initial meeting with Jahangir, Roe had abandoned all hopes of a formal treaty. In February 1618, while writing his yearly report to the Company, Roe noted that it was useless to attempt to win the friendship of the Indians for "they are weary of us. Wee have emproverished the ports and wounded all their trade. I knowe that these people are best treated with the sword in one hand and caducean in the other."16In the same communication, Roe threatened to seize Indian shipping until "those conditions bee offered which now I seeke with despayre.17

Roe was eventually able to gain some concessions from Khurram, Jahangir's son and successor. These concessions were granted in the overall context of growing hostilities between the Portuguese and the Indians and in exchange for Roe's offer to protect Indian shipping. The concessions agreed to by Khurram were a much scaled down version of Roe's original demands: no tolls were to be levied on goods passing to or from the port; the factors were to be permitted, under certain restrictions, to hire any house they pleased for a "factory"18; they could govern themselves according to their own religion and laws. However, permission to buy or build a permanent dwelling was refused and an attempt was made to limit the number of Englishmen permitted to bear arms in the city. According to historian William Forster, Roe was determined not to yield on the latter point, which was eventually conceded on the agreement "that during the abode of the English at Suratt they shall do no wrong or hurt to any."19

These gains were a significant factor in the development and expansion of the East India Company. The exchange of letters between Jahangir and James was also of symbolic importance, especially in view of the indifference and, at times, contempt the Mughal officials displayed toward foreign traders and rulers. As William Forster puts it, "that the Franks should send an ambassador to the imperial court was by no means unwelcome as a tribute to its splendour and fame, but that they should seriously claim to be treated on terms of equality was not to be thought of."20In such a context, the procurement of a reply from Jahangir to James was a significant achievement. Jahangir wrote:

> Upon the assurance of your royall love, I have given my generall command to all the kyngdomes and ports of my dominions to receive all the merchants of the English nation as the subjects of my frend; [T]hey may have free libertie without any restraynt; and at what port soever they shall arrive that neyther Portugall cytty nor any other shall dare to molest their quiett; I have commanded all my governers and capteynes to give them

freedome answerable to their own desires: to sell, buy, and to transport into their countrie at theire pleasure. [L]et your throne bee advanced higher; among the greatnes of the kyngs of the prophett Jesus lett Your Majestie bee the greatest, and all monarchques derive their councell and wisedome from your brest as from a founteyne, that the law of the majestie of Jhesus may revive and flourish under your protection." 21

The above lines were written sometime in 16161617, and in the 150 years or so that followed, Britain came to acquire one of the largest, most populous lands ever to be colonized.

To map out the larger structural context of the first institutional contacts between the Europeans and Indian society, the growing significance of maritime trade and the charting out and consolidation of existing and new networks of sea routes seem to be obvious starting points. One can go back in history to the first millennium B.C. when maritime trade, controlled by the Arabs, was thriving between the Red Sea and northwest India.22However, trade is better documented during the Hellenistic and Roman periods when the routes from the Mediterranean to the northern and western parts of India were more established. Thus the *Periplus of the Eurythraean Sea*, written sometime in the first century A.D. indicates the presence of navigation manuals for the sea route to India.23Pliny, in the early first century, provided a detailed description of the routes to Indian ports through Egypt, and Ptolemy's geography included a description of the Malabar coast of India.24The Romans imported a number of items like precious stones, cotton, silk, and spices, and paid with precious metals and gold coins, hoards of which have been found in the coastal regions of southern India.25Commenting on the drain of wealth from Rome to India, Pliny remarked, "The subject is one well worthy of our notice, seeing that in no year does India drain us of less than 550,000,000 sesterces giving back her own wares, which are sold among us at fully 100 times their first cost."26

Vasco Da Gama and the Consolidation of Estado da India

Prior to the arrival of Portuguese traders on the coast of Malabar in the late fifteenth century, there were a number of trade routes and networks connecting India with Europe as well as the Arabian peninsula and Southeast Asia. Although such routes and systems of trade were invariably affected by the changes in empires, they formed the backdrop for the landing of Vasco da Gama's ships in Calicut in 1498 on a quest for "Christians and spices."27By the time Vasco da Gama navigated the Cape route to India, shipping trade between the western coast of India and the Red Sea was well established. One

of the first projects of the Portuguese was to establish outposts on the coasts of India, which, coupled with naval superiority over Asian ships, would help them to confront the rival Muslim traders and settlements. The settlement of the first Portuguese fort, with help from the ruler of Cochin in 1503, followed by the eventual capture of the island of Goa in 1510 under the governorship of Alfonso de Albuqerque, laid the foundation of the future maritime empire that became known as the *Estado da India*. 28The naval superiority of the Portuguese enabled them to take almost complete control of the maritime trade along the Indian coastline. The control of the sea routes and of the maritime trade of land-based states and empires of India was a relatively new concept in the Indian subcontinent. Indigenous shipping and trade were permitted, but were subject to tribute in the form of the *cartaze* system. This system involved buying passes from the viceroy of Goa to avoid seizure and confiscation of merchandise of the Indian ships. According to the historian K. N. Chaudhuri,29the *cartaze* system was justified by Portuguese legal authorities by invoking the papal mandate granting quasi-political jurisdiction over Asian waters. Most Indian rulers seem to have acquiesced to this system. These included the sultans of Bijapur and the Mughal emperors who licenced their ships charting the trade route from Surat on the west coast to Mocha in the Middle East.

The Portuguese were able to amass a great deal of wealth, both due to the revenue earned by the *cartaze* system and through some inter-Asian trade of their own. Over a period of time, however, the attempt to control the maritime trade foundered due to "corruption and administrative laxity on the part of their officials in the Indies."30As Fernand Braudel has argued, the Portuguese were effectively turned into customs officials due to their inability to cut off the Mediterranean spice trade.31In any event, the Portuguese were unable to claim a monopoly on spice trade in the East

Indies.

The Dutch Company and Anglo-Dutch Rivalry

The seventeenth century saw the decline of the Iberian powers as well as the founding of the English East India Company (henceforth EIC) in 1600. Just two years later, a number of Dutch trading companies merged to to form the *Vereenigde Oost-Indische Compagnie*, or VOC. Both of these trading companies had to reckon with the Portuguese as their main rival. In the initial stages, both the English and the Dutch companies focused their attention on the Indonesian archipelago and the Spice Islands, where the Portuguese hold was tenuous. Eventually the Dutch vessels proved to be far superior to those of the Portuguese, and they were able to challenge the latter's near monopoly of the spice trade. In due course, the Dutch company (VOC) was able to replace the Portuguese in controlling the inter-Asian trade. The EIC attempted the same, but it was not as successful. In the long run, however, both the VOC and the

EIC engaged in direct trade with Europe with greater vigor than the erstwhile Portuguese who had concentrated mainly on the inter-Asian trade. For K. N. Chaudhuri, "the Dutch and English methods of trade in the Indian Ocean incorporated a much greater degree of mercantile and economic spirit than was the case with the Portuguese." 32

With the ascendency of the Dutch VOC, attention began to be focused on the possibility of trading in cotton and silk textiles, various varieties of which were being manufactured in different regions of India. Cotton textiles, of course, constituted a central commodity of exchange in the inter-Asian trade in the Southeast Asian trading circuit. Cotton textiles were an essential barter commodity to be exchanged for spices and pepper. But textiles had so far been involved mainly in trade within the Indonesian archipelago. The change, which came in the wake of the Dutch VOC and the EIC, was the attempt to diversify the trade in spices and to organize direct trade between India and Europe in cotton textiles. Both companies attempted to gain footholds in regions engaged in the manufacture of cotton textiles. These included the Coromandel and Bengal regions on the east coast and the Gujarat region on the west. Eventually the Dutch were able to obtain concessions through their naval power or through permission from the local rulers as well as the local officers of the Mughal empire, to set up "factories" at a number of places both on the east and west coasts. Setting up these factories also involved naval battles to blockade or dislodge Portuguese trading establishments. Although not always totally successful, this policy eventually led to the establishment of factories of the Dutch VOC at the port cities of Surat, Cochin, Pulicut, Negapatam, Masulipatam, and Hugli.33

While the Dutch VOC was in the process of gaining a foothold on the coastal areas of India, the EIC was sponsoring exploratory voyages to south and Southeast Asia. In the process of attempting to establish a presence in the trading circuits of south and Southeast Asia, the EIC had to contend with two main problems. One of these was the fact that the Dutch, especially after their success against the Portuguese, were not willing to tolerate trade rivals in the area. The second problem was that the commodities available for trade in Southeast Asia did not have such a ready market at home. Thus English markets were rather restricted when it came to pepper and spices, which were the chief commodities to be had from Southeast Asia. While awareness of the naval might of the Dutch induced the EIC to dispatch large fleets of ships, the consequences, at times (i.e., in 1603), led to a glut of pepper in England when ships returned with nothing but pepper.34It was the awareness of such problems that provided the impetus for the growth of re-export trade in Europe and the attempt to establish trading posts in Gujarat, the Coromandel coast, and eventually in Bengal, which was to prove what historian P. J. Marshall has called the "British Bridgehead."35

The Ascendency of the East India Company

It was against this background and the attempt to confront problems associated with the competition from the Portuguese and the Dutch that the directors of the EIC appointed Thomas Roe as an official ambassador from James I to the Mughal emperor Jahangir in 1615. Although the first permanent factory on the west coast of Surat was founded in 1613, it was far from secure, and the *farman* obtained by Roe opened the way to further settlements and strengthened the position of the East India Company on the Indian subcontinent. Disputes between the trading companies and the Mughal authorities

continued, usually over the payments of customs or other financial dues. Conflicts between the Dutch, Portuguese, and English companies continued too, until the eventual dominance of the latter in mid-eighteenth century. It was eventually the *farman* from the Mughal court in 1717 that made the EIC's trade customs free throughout the imperial territories in return for an annual tribute of 3,000 rupees. 36The imperial decree of 1717 was issued against the background of a number of conflicts between the trading companies and the Mughal authorities. It represented a compromise to end repeated hostilities involving cutting off supplies to the "factories" and blockading Mughal ports by the navies of the trading companies. Nevertherless, the *farman* of 1717 became one of the cornerstones of English commercial and political policy in India.

The East India Company and the Cotton Trade

However, it was the growing volume of trade in one particular commodity that contributed to the entrenchment of the English in India and, simultaneously, had far-reaching consequences for industrialization and the development of capitalism in Britain. As mentioned earlier, the initial impetus for setting up the EIC was competition with the Dutch company over the spice trade. For a long time spices constituted the main item of the EIC's trade, especially in the Southeast Asian trading circuit. But, since demand for spices in Europe was rather limited, the EIC began importing calicoes and other textiles into Britain in the early seventeenth century. The first entries of calicoes appear in the Company's records in 1602. By 1634 about one hundred thousand pieces of the fabric were being imported to England.37In the years that followed, a number of factors contributed to a shift in fashion in England from French linens and other locally woven silks to the imported textiles from India. One such factor was the strict prohibition on importing French linens and silk during that time. Although in 1684, during the reign of James II, Parliament abolished the prohibition, heavy duties on French imports were levied. In the aftermath of the 1688 revolution, French goods were prohibited once again, and this provided

another opening for the EIC. 38By this time, the import of textiles of various kinds monopolized the volume of goods being imported, and traditional items like spices, indigo, and saltpeter constituted a very small fraction of the total volume. However, while the prohibition on French textiles created an opportunity for the EIC to increase the volume of cotton textiles being imported to England, this factor by itself does not explain the overwhelming popularity acquired by Indian textiles in a fairly short space of time.

Fashion, Culture, and Consumption: the "Calicoe Craze" in Britain

During the latter part of the seventeenth century, certain changes in fashions, taste, and cultural patterns enabled the incoming calico, muslin, chintz, and silk from India to be valued by the English population. The textiles seem to have had an appeal that cut across class and status lines, and, within a short period of time, calicoes seem to have literally become a part of the daily fabric of life of a diverse range of people in England. Several historical and cultural factors seem to have coincided with the prohibition of fabrics from France in giving rise to the sudden high esteem accorded the textiles from India. The late seventeenth century witnessed a growing centralization of English cultural, political, and economic life in London, and the court life of the Restoration served as a focus for English fashion. Charles II was a great admirer of French culture and readily copied the "court-life of his pompous cousin across the Channell."39The prohibition on French goods in 1678, in retaliation against a similar act prohibiting English cloth in France in 1677, created an unmet demand for high-quality imported textiles. However, the English did not return to the use of the local woollens and silks as they were not deemed fine enough for high fashion.40

The cultural trend, which bestowed high esteem on imported textiles, was transferred to fabrics from India. The ban on French linens and the cultural preference for the fine cottons being imported from India did not go unnoticed by the directors of the EIC. One of them noted that "the calicoes and chintzes had become the wear of the ladyes of the greatest quality, which they wear on the outside of gowns and Mantuas which they line with velvet and cloth of gold."41Members of the nobility and other elites also used cotton textiles from India, and it was claimed that Mary II was the first "to set the fashion of using chintz and East India Calicoes in dress."42At the same time, the English were being told of the preference of elites in India for "those excellent fine cotton Linens, made herein in great abundance, and of all colours, and interwoven with divers sorts of Loom-works and flowers, very fine and cunningly wrought and better esteemed here than Silk."43

It was, of course, the fine quality and low cost of the Indian fabrics that made them so attractive to the elite of Britain. A number of earlier travelers and writers have commented on the quality of the calico, chintz, and muslin from the various regions of India. In Roman times there were references in the *Periplus* to the fine muslins from the lower valley of the Ganges; in the Middle Ages, Marco Polo noted that "Masulipatam produced the finest and most beautiful cottons found in any part of the world"; later the French traveler Tavernier remarked that "some calicoes are made so fine that you can hardly feel them in your hand, and the thread when spun is scarce discernable. [W]hen a man puts it on, his skin appears quite plainly as if it were quite naked." 44Commenting on a particularly sheer variety of muslin known by the evocative name of *Shabnum*, or "evening dew," E. Baines remarked that it "might be thought the work of fairies or of insects rather than of men."45In any case, the quality and variety of the fabrics, combined with affordable prices due to the lower costs of production in India, contributed to their popularity in all classes of the English population. In fact, some of the fabrics had been used first by the poorest people as "shrouds for the dead among those who could not go to the price of linen and yet were willing to imitate the rich."46However, once the finer varieties took hold of the imagination of the elite, the fabric's appeal cut across class lines, a fact that prompted the writer and satirist Daniel Defoe to comment that it had become difficult for the "gentry" to "know their wives from their chambermaids."47

The shift in fashion and taste from the French linens to Indian cotton had a number of repercussions on the English woolen and silk industry. The hope that a ban on French products would help the silk and wool industry did not materialize, and the sudden switch in fashion and taste, together with the spurt and continued growth in the consumption of textiles imported by the EIC, had a negative impact on it. Economic historian P. J. Thomas has argued that Indian textiles were not the sole cause of misery and unemployment of the silk and wool weavers. According to him, other causes included the war with Spain and the concomitant dislocation of trade with Spain and the Spanish colonies, which were important consumers of English products. Strained relations with Russia affected trade as well.48But whatever the causes, the import of cottons by the EIC did have a considerable impact on the local industry as evidenced in the flood of pamphlets, poetry, etc., attacking not just the calicoes but also the people who consumed them. The prevailing attitude of the times are summed up in the pamphlet titled *The Trade to India Critically and Calmly Considered* (1720), whose author graphically observed that "Europe like a body in warm bath with its veins opened lies bleeding to death and her bullion which is the life blood of trade flows to India to enrich the Great Moghul's subjects."49

Reaction Against the Consumption of Indian Cotton: The "Calicoe Bill" of 1720

The weavers' riots that followed in 1719 were triggered partly as a consequence of these perceptions of the impact of the import of calicoes on the local silk and woolen industry. Those who wore Indian cotton were harrassed by the "calico-chasings" initiated by the affected weavers and their supporters. Women wearing calicoes had them stripped off their backs, and there were some cases where acid was thrown on their clothes. There was resistance from some quarters, but three women, who, in a show of defiance, came dressed in calicoes by coach to the area of Spitalfield, where the silk weavers were most affected, were not so lucky. According to one chronicler of the event, the weavers stopped the coach and "stripped them as clean of the calicoes as a butcher does a partridge of its feathers." 50By 1720 there was enough pressure on the parliament for the introduction of what came to be known as the "Calicoe Bill," which stipulated that the "use of all printed, stained and dyed calicoes and linens in apparel household furniture and otherwise, except such as are the produce of Great Britain and Ireland, be prohibited after a certain time to be appointed." Despite the arguments of the directors of the EIC to the effect that their chief settlements in India were in the "Calico countreys" and that "if calico was prohibited in England they (i.e., the Company) would become contemptible in India," the bill soon became an act in 1720. December 25, 1722 was the date from which the use or wear of all "printed, painted, stained and dyed calicoes" of non-British and non-Irish origin was banned. However, it seems that the taste for the calicoes did not subside that easily and some people continued wearing the banned articles, provoking Daniel Defoe to quip, "two things among us are too ungovernable, viz., our passions and our fashions."51

The Ban on the Consumption of Indian Cotton: Consequences for Britain and India

The continued high demand and taste for calicoes constituted one of the major factors in the stimulation of cotton

manufacture in Britain. Techniques of printing on textiles became further refined, and, barely a dozen years after the prohibition on Indian cotton, John Kay had invented the fly shuttle for weaving. Within the next thirty years, Hargreaves, Arkwright, and Crompton contributed to further inventions that were to turn Lancashire into the world's major producer of cotton textile. Cotton textile, manufactured from staple, which was not grown in Britain, became one of the major factors in fueling the Industrial Revolution. As E. J. Hobsbawm has observed, "Whoever says

Industrial Revolution says cotton, the cotton industries of Lancashire and Manchester." 52The EIC continued to export Indian products to various regions of continental Europe, but the manufacture of cotton in India showed a steady decline after the ban. The ban on Indian goods was eventually lifted, but only after the British cotton industry with the aid of the new power looms, had become well established. Even then, by 1813, prohibitive duties were imposed on textiles being imported from India, while cheaper cotton textiles produced in Britain entered the Indian market. The timing of the initiation of the export of British manufactures to India was significant: It came when Napoleon Bonaparte had banned the import of British commodities to France.53

Commenting on the excessive prohibitive duties imposed on the import of textiles in India, H. H. Wilson, a nineteenth century administrator observed:

> It is also a melancholy instance of the wrong done to India by the country on which she has become dependent. Had this not been the case, had not such prohibitory duties and decrees existed, the mills of Paisley and of Manchester would have been stopped in their outset, and could scarcely have been again set in motion, even by the power of steam. Had India been independent, she would have retaliated, would have imposed preventive duties upon British goods, and would thus have preserved her own productive industry from annihilation. This act of self-defence was not permitted her; she was at the mercy of the stranger.54

In a similar vein, Karl Marx observed that "till 1813, India had been chiefly an exporting country, while it now became an importing one. [T]he great workshop of cotton manufacture for the world since immemorial times, became now inundated with English twists and cotton stuffs."55

The irony of the imposition of prohibitive duties at that particular time in history lies in the fact that theories of laissez-faire had already been formulated by Adam Smith and Ricardo. The principle of noninterference by government in regulating economic affairs through the invocation of the "hidden hand" was not to be applied in the case of the trade relationship between Britain and colonial India. As Hobsbawm, amongst others, has pointed out: "The one exception was India. Its abnormality leaps to the eye. It was, for one thing, the only part of the British Empire to which *laissez-faire* never applied. Its most enthusiastic champions in Britain became bureaucratic planners when they went there."56The debate and literature on the consequences of the policy of prohibition of imposing heavy duty on incoming Indian goods, while at the same time allowing machine-produced British goods into the Indian market, is extensive. Whether the "thesis of deindustrialization," i.e., whether this policy led to the gradual deindustrialization of India and the industrialization of Britain, is accurate or not is still being hotly debated.57What seems beyond doubt is the fact that colonial policies of the day had a devastating impact on cotton manufacture of India. As Henry St. George Tucker wrote in 1832: "The

cotton fabrics, which hitherto constituted the staple of India, have not only been displaced in this country but we actually export our cotton manufactures to supply a part of the consumption of our Asiatic possessions. India is thus reduced form the state of a manufacturing to that of an agricultural country." 58On a similar note, Montgomery Martin reported to the Select Committee of 1832: "The decay and destruction of Surat, of Dacca, of Murshidabad and of other places where native manufactures have been carried on, is too painful a fact to dwell upon. I do not consider that it has been in the fair course of trade; I think it has been the power of the stronger exercised over the weaker."59Finally, Marx borrowed the more graphic words of the governor-general to convey a sense of the impact of this policy of unfree trade on the population of India: "English cotton machinery produced an acute effect on India. The Governer General reported in 182435: 'The misery hardly finds a parallel in the history of commerce. The bones of cotton weavers are bleaching the plains of India.'"60

Competition for Markets and Commodities: The Anglo-French Rivalry in Coastal India

However, to flood India with cotton produced by the power looms, the British first had to gain ascendency over other rival powers like the Dutch and the French. The EIC also had to gain actual control over Indian territories. And this was anything but a smooth process. It was hardly a case of the British deciding on a clear-cut colonial policy and putting it into practice just as they pleased. It was a complex and, at times, convoluted process that involved a mix of the implementation of specific policies and their unintended consequences.

By the mid-eighteenth century, the English had surpassed the Portuguese and Dutch companies and had become the dominant power where trade in the coastal regions of the Indian subcontinent was concerned. However, before achieving this position of dominance, the English East India Company had to contend with another European competitor in the area. This was the French *Compagnie des Indes Orientales*, which, although set up as early as 1664 by Colbert, emerged from a relatively weak position to that of a powerful competitor in the early decades of the eighteenth century. It was this competition that was to develop into armed Anglo-French confrontation on the Coromandel coast against the background of the erosion of the central authority of the Mughal empire and the outbreak of factional conflicts, wars of succession, and rivalries among the regional powers. The eventual establishment of English territorial power in India, starting with the Battle of Plassey in 1757, occurred against the background of relatively rapid social change within the erstwhile centralized Mughal empire. A number of conjunctural factors, or

"historical accidents," together with the culmination of certain long-term structural trends both within and without India, contributed to what Immanuel Wallerstein has termed "the incorporation of [the] Indian subcontinent into [the] capitalist world-economy." 61

Internal and External Factors in the Consolidation of British Colonial Power

It is of course hard to assign priority to any one factor contributing to the eventual consolidation of British colonial power; the process, which was by no means smooth or uncontested, has to be understood in the context of certain pronounced structural transformations that were set in motion due to the activities of the trading companies. The changes occurring within Indian society were closely intertwined with the phenomenal growth in the volume of maritime trade, and it had a number of significant consequences not only for the social structure of the coastal areas but for the remote hinterlands as well. One of the most striking changes which was evident after the death of the Mughal emperor Aurangzeb in 1707, was the decline, fragmentation, and eventual "collapse" of the erstwhile relatively centralized Mughal empire.62The factors that contributed to the decline of empire have been matters of intense research and heated debate. Social historians have offered a number of explanations for the rather sudden erosion of Mughal central authority from the early to mid-eighteenth century.

The eminent historian Irfan Habib has argued that the main reason for the collapse of the empire after Aurangzeb's reign lies in the culmination of certain contradictory tendencies at work.63Habib contends that the centralized administration of the empire, which relied on intermediaries like *jagirdars* and *mansabdars* for the collection of revenue, sought to raise enough revenue from the peasantry to maintain its massive army. Quite often however, the interests of the intermediaries were at odds with that of the central administration, and the tendency to extract excessive surplus from the peasantry in order to save a substantial portion for themselves led to a number of problems. These included armed resistance by the peasantry, flight from the land, and decline in cultivation, all of which undermined the economic basis of the empire.64Fernand Braudel has relied extensively on the work of Irfan Habib and other historians to construct a broadly similar argument. For Braudel, central to the imperial system under the Mughals was the strength of the army, which was of a size that would have been "unthinkable in Europe: almost 200,000 horsemen, plus over 40,000 matchlockmen or gunners."65To a large degree, the army itself was the government, with the *mansabdars* being the commanders of the force. The state kept by the *mansabdars* and *jagirdars* was

almost as grand as that of the emperor himself, and the aristocracy constituted a heavy burden on the Indian economy,

"living as it did from grants paid directly out of the imperial treasury, or from the dues paid by peasants on the *jagirs* granted their masters by the empire, to maintain their rank." 66

During the early years of his reign, Aurangzeb was successful in meeting most challenges to his authority, including a rebellion led by his son in 1680. However, in the years that followed, a number of provincial rulers began to question the authority of the emperor. Local *nawabs*, *mansabdars*, and *jagirdars* began to seize any occasion to increase their revenues and profits, and some succeeded in transforming life-holdings into hereditary property.67Even when Aurangzeb subjugated two independent Muslim states of the Deccanthe kingdoms of Bijapur (1686) and Golconda (1687)the crisis of insubordination from other quarters, especially from the Marathas, increased dramatically. Already the prestige of the emperor had been eroded substantially when in 1664 the Marathas had succeeded in capturing and sacking Surat, the wealthiest port in the empire and an important symbol. In the long run, the continuing war with the Marathas in the Deccan proved to be, in Irfan Habib's words, "the greatest single force responsible for the downfall of the Mughal empire."68The Marathas' successful resistance to the payment of tribute to the emperor exposed the frailty of the Mughal authority and contributed to rebellions in other provinces. Aurangzeb's preoccupation with the Deccan region and his wars against the Marathas left little time for the effective exercise of authority over other regions, and encouraged the powerful members of the nobility, or *mansabdars* and *jagirdars*, to assert their autonomy and independence. Moreover, those *jagirdars* who chose to remain loyal to the emperor were forced to extract an increasing amount of revenue from the peasantry to fund the continual military campaign in the Deccan region. Such a situation led to numerous peasant revolts and flights from the land.

Toward the latter part of the regime of Aurangzeb, the rulers of a number of regional states, who until then had recognized the authority of the emperor at Delhi, began to assert independence. By the time of his death in 1707, Aurangzeb's successors had actual control and authority over little more than Delhi and the surrounding area. At this juncture, the Marathas, who posed the greatest challenge to the Mughals during Aurangzeb's regime, attempted to capture Delhi but were eventually defeated by the invading armies of the Afghans in 1761 at the battle of Panipat. Overall the eighteenth century represented a steady decline of Mughal power, and conditions were in a state of flux, leaving many regional contenders in conflict with each other over territory and control of revenue. In addition to the many indigenous regional contenders for power, there was another key institution that had steadily emerged as a new center of power. This was the English East India Company, which, building on the growing volume of its trade in the region, attempted to consolidate its position in Bengal.

It was at this historical juncture, against the background of the disintegrating Mughal empire and the ensuing conflict between some of the regional contenders for power, that the English, after having overcome challenges from the Dutch and the Portuguese, came to acquire control of Bengal, the most productive and richest region of India. Following the work of the social historian Chris Bayly, 69three key elements of the rapid structural transformations in eighteenth-century India can be delineated. First, there were cumulative indigenous changes reflecting growing commercialization, the emergence of new social groups, and political transformation within the subcontinent. Secondly, the eighteenth century witnessed a wider crisis in west and south Asia, signalling a decline not only of the Mughal but also of the Ottoman and the Safavid empires. Finally, the same period witnessed the massive expansion of European production and trade and the emergence of more aggressive nation states in Europe, developments that influenced the assertive policies of the EIC, especially after the Battle of Plassey in 1757.

The significance of the growth of commercialization and the consequent formation of new social groups cannot be overemphasized. One of the effects, already discussed, was the accumulation of economic power by the landed gentry and the concomitant assertion of autonomy from the seat of power in Delhi in the eighteenth century. Another consequence of the increasing commercialization was the emergence of powerful indigenous merchants, bankers, and moneylenders, who provided economic support for the new local kingdoms and provincial magnates. As Bayly and other historians have argued, the decline of the Mughals resulted partly from the very success of their earlier expansion.70The very commercial growth that had earlier provided the supports for power in Delhi ultimately eroded it. In a sense then, the decline of the Mughal empire was the culmination of what Max Weber would have described as one of the "unintended consequences" of the creation of new wealth and social power in the provinces, where it could not be easily controlled by the distant monarch in Delhi.71The moneylenders, merchants, and powerful bankers who provided economic support first to the Mughal empire, then to the newly emergent provincial powers, later extended the same kind of support for the expansion and consolidation of British colonial power.

These developments facilitated Robert Clive's victory at the Battle of Plassey in 1757 and eventually led to the consequent control by the Company of the most prosperous region of India. By the mid-eighteenth century, the successors of the *diwan* of Bengal, appointed by the Mughal emperor, had become virtually independent dynasts or *nawabs*. In the meantime, the powerful bankers and merchants like the *Jagat Seths* (literally, bankers to the world) had prospered due to the increasing commercialization and had come to centralize all aspects of state and *zamindari* finance in their hands. They controlled the Bengal mint, remitted the periodic payments to the Delhi court, and increasingly became financiers for the British in inland markets.72

Structure and Agency: The Battles of Plassey (1757) and Buxar (1764)

The accession to power of Siraj-ud-Daula in the province of Bengal in 1756 provided the occasion for a crisis. The new ruler attempted to consolidate his power by squeezing resources out of the large *zamindars* and the Jagat Seths. At the same time the British began fortifying Fort William, or Calcutta, partly due to fear of attacks by the French and partly to insulate themselves from the rapidly changing political situation. This brought about a souring of relations between the English and the new ruler of Bengal. The friction was further exacerbated when the English company refused to send the customary tributes and presents to the new ruler. Siraj-ud-Daula interpreted this move as a virtual declaration of war and attacked the fortification in Calcutta, forcing the English to flee.

All these changes came at a time when the fortunes of the indigenous merchants and bankers had become closely intertwined with those of the EIC. The company was, after all, importing bullion and was buying the productions of their *zamindaris* and their trade goods. 73Siraj-ud-Daula's action in expelling the English from Calcutta alienated a number of very powerful factions in his region, especially the very wealthy Hindu and Jain merchants and bankers, whose fortunes had become quite closely intertwined with those of the Company. These factions began plotting the overthrow of the Siraj-ud-Daula, and in this process they were offered support by relatives of the ruler. More importantly, the conspirators were offered support by the British. In April 1757, Robert Clive, commander of the Company's forces in Madras noted that the conspiracy against Siraj-ud-Daula was led "by several of the great men, at the head of which is Jugget Seit himself."74In June the same year, Clive committed British support to the conspiracy, and, in August 1757, the Battle of Plassey between the forces of Siraj-ud-Daula and those of Clive ended in defeat for the former and resulted in the installation of the new ruler, Mir Jafar, who was partly in control of the EIC.

As Chris Bayly has argued, such "fiscal conspiracies" were not uncommon incidents in Indo-Islamic history, and a number of key figures, including Haider Ali of Mysore, came to power in this manner. What was significant about the Battle of Plassey was that it brought the richest province of India in control of the East India Company in the context of a system of world trade in which Britain was rapidly emerging as a dominant power. Another key factor was that the particular form of commercialization in late Mughal India worked to the advantage of the EIC. Vigorous commodity trade and the inroads of fiscal entrepreneurs under the *nawabs* had resulted in the marketing of "shares" of a whole range of enterprises. The Company succeeded in securing control of monopolies of valuable products like saltpeter, salt, indigo, and betel nut.

Another development was the fact that after Plassey in 1757, Company servants penetrated the hinterlands and began amassing huge fortunes by using political influence to gain privileges and exemptions from Mughal custom dues. This development again led to friction between the Company and Mir Qasim, the "client ruler" of Bengal, culminating in the Battle of Buxar in October 1764. Mir Qasim, the *nawab* of Bengal and his ally, the *nawab* of Avadh, were defeated in the Battle of Buxar, which allowed the Company to achieve complete control of Bengal. This control was further formalized in 1765 when the Company was granted the *diwani* of Bengal, or the formal right to collect revenues, for the region as the *diwan* of the Mughal ruler in Delhi.

The Battle of Plassey 1757 and the subsequent formal control of the region of Bengal by the East India Company in 1765 were in a sense made possible by the fortuitous conjuncture of certain long-term historical and social trends both within

and without India. It is true, as Chris Bayly and David Washbrook 75have asserted, that the growing commercialization and development of markets, with further stimulation of these trends by the European maritime trade, helped in constituting the structural conditions for the onset of British rule in India. There is no doubt that Bayly is correct in arguing that Indian capital represented by the *Jagat Seths* and other bankers and merchants along with the *zamindars* of Bengal provided the support and the occasion for the British coup in Bengal.76Following Anthony Giddens' "structuration theory,"77it is also true, sociologically speaking, that "Indians remained active agents and not simply passive bystanders and victims in the creation of colonial India."78There are, however, problems with pushing such an argument to the extreme. David Washbrook, for example, while usefully reminding us of the need to relate the development of colonialism to some of the specific structural changes in south Asia, arrives at the surprising conclusion that "colonialism was the logical outcome of South Asia's own history of capitalist development."79

In his eagerness to ascribe agency to the the Indian actors in the development of colonialism, Washbrook tends to make British colonialism the inevitable response to events unfolding in the Indian subcontinent. This argument robs the early British adventurers and the later colonial administrators and colonial state of any role or agency in the whole process. The EIC suddenly becomes an unwitting and passive victim, helplessly drawn into the vortex created by the social changes occurring in India. Such an argument also ignores, or at least minimizes, the dynamics of sociohistorical developments on an international scale and, more importantly, in the "home" country, i.e., Britain. Specifically in the case of India, although the social changes stimulated by the growth of commercialization created the conditions for the English control of Bengal in the first instance, a number of "external" factors in England and in the international trading circuit helped in the decision to take over the control of administration of the territories acquired in the aftermath of Plassey and Buxar. The decision to accept the *diwani*, or revenue collection, of Bengal on behalf

of the Mughal emperor, was evidently a decision quite consciously made and was not in any way forced on an unwilling East India Company by changes in the social and political structure of the region. In any case, Washbrook's remark does not enable us to understand why it was only the English and not the French or the Dutch company that came into the possession and control of Bengal.

It is clear that for a trading organization like the EIC the costs involved in the administration of Bengal were substantial and could not have been overlooked by its Board of Directors. As K. N. Chaudhuri has argued, political or imperial adventures in India were frowned upon by the board of directors of the Company for the same reasons that opening new factories was not encouraged in the earlier periods. 80As far as the Company was concerned, such adventures increased overhead costs and did not result in immediate financial returns. In the past, Thomas Roe had advised the English officials to "keep to this rule if you look for profit: seek it out on the seas and in peaceful trading; for there is no doubt that it would be an error to maintain garrisons and to fight on land."81Actual experience had also taught the Company's directors to avoid confrontation in India. For example, in 1688, Josiah Child, director of the East India Company, had instigated and lost a war against the Mughals.

Nevertheless, the situation had changed substantially by the mid-eighteenth century, and despite the many objections of some members of the Court of Directors, the political acquisition of Bengal became a reality. At about the same period, there were objections in England to the export of bullion to finance the trade of the Company, but soon enough the substantial revenue accruing from the acquisition of Bengal began to pay for the trade. The acquisition of Bengal proved to be very profitable as the outflow of bullion from England ceased and the inflow of cotton and other goods into Britain continued uninterrupted. This happened during a time of great financial strain for the British state partly due to the American Revolution. Under such conditions, the inward flow of revenues from the Indian subcontinent was not unwelcome.82Robert Clive's promises of limitless wealth in the Indian subcontinent and the argument for military conquest struck a responsive chord under the circumstances. In the short run, there appeared to be a justification for direct colonization of the province of Bengal.

As Immanuel Wallerstein83and others have pointed out, the increasing Anglo-French rivalry84was also a significant factor in the consolidation of direct control over the region of Bengal. The acquisition of Bengal, in addition to helping Britain in controlling a new zone of the emerging world system, indirectly enabled Britain to resolve a state financial crisis of the 1780s that France was unable to surmount. Such a situation led the British government to get involved more directly in the control of the newly acquired territory. Lord Stormont's objective of "a strong government in India, subject to the check and control of a still stronger government at home"85was realized with Pitt's

India Act of 1784, which led to the creation of the Board of Control and placed the activities of the Company under the direct supervision of the British Parliament. These considerations were some of the key factors that led to the direct involvement of the British state in matters pertaining to India.

Over a period of time, not only the outflow of silver from Britain ceased, but bullion from Bengal actively helped in the conquest and administration of several other regions in the subcontinent. 86Even when the costs of administration of the territories acquired in India proved to be greater than what was anticipated initially, the preservation of the East India Company's trade with China was offered as a reason for the continued control of Indian territories.87The argument was that because Britain controlled India, it could create export crops that would find a market in China, where, unlike India, a restructuring of production processes was not possible. In 1793 when the renewal of its charter came up, the Company was able to retain its monopoloy over the China trade and some monopolies in India. The same year saw the implementation of the Permanent Settlement Act of Cornwallis, which represented the culmination of a process of legal and administrative reform that had the effect of removing barriers to treating land as a commodity to be bought and sold on the market.88

Resistance to Colonial Rule: The War with Tipu Sultan and the Acquisition of Mysore

Due to a number of internal and external factors, the EIC was able to acquire Bengal, Bihar, and Orissa without encountering too much overt resistance. However, further expansion of the EIC did not go unchallenged. Sustained resistance was offered by the Marathas and the forces of Haider Ali and his successor, Tipu Sultan of the state of Mysore. On a number of occasions, the Marathas came close to defeating the armies of the EIC, but ultimately the British were able to exploit the weaknesses resulting from divisive patrimonial conflicts over succession. Despite spirited resistance, "the Marathas 'failed' in part because the rapid expansion of their polities created fractures which a European state and army could consistently exploit."89

The armies of Haider Ali and Tipu Sultan represented real and sustained threats to further expansion of the Company's power. These threats came in a series of military encounters between the army of the EIC and those of Haidar Ali and, later, his son and successor Tipu. Haider Ali, the ruler of Mysore, had already attracted the attention of the British due to his stands against them in the 1770s and 1780s in which he had not been subdued. In fact for a number of years, Haider Ali and Tipu Sultan had posed serious threats for the expansion and consolidation of British colonial rule in India. After failing in their campaign against Haider Ali, the British targeted Tipu, who became the object

of military encounters and well-orchestrated ideological and propaganda campaigns in Britain.

The war between Tipu's armies and those of the East India Company was a long and drawn out affair and a lot was at stake on both sides. Although the soldiers of the EIC had been unable to subdue the armies of Haider Ali, the story was slightly different in the case of Tipu Sultan. In a series of military engagements, including the Third Mysore War (17901792) which resulted in the surrender of some territory to the Company, the final encounter at Seringapatam in 1799 led to the defeat of the forces of Tipu and the passing of all of the territories of Mysore into the hands of the British.

Tipu: the Ideological Construction of an "Oriental Despot" and the Legitimation of the British Conquest of Mysore

Throughout the military campaigns against him, Tipu, like his father before him was the target of an organized propaganda campaign by the British, both in India and in Britain. In the case of Mysore, it was argued that most contemporary Indian rulers were usurpers of previous dynasties and rights and, specifically, that Tipu Sultan had "violated the law and intercourse of nations" and had destroyed the basis of landed property under the "ancient Hindoo constitution." According to Mark Wilks, who was Wellesley's political agent and a resident in Mysore, the aim of British policy was to restore this ancient constitution and the Hindu Wodiyar house that had existed before Haider Ali's takeover

in 1761. 90Such an argument was used by the British, both to legitimize the campaign against Tipu in the eyes of the local populace and to deny the legitimacy of his rule. Parenthetically it may be noted that the policy was reversed when the British dealt with Mughal authority. Not only was no attempt was made to deny the legitimacy of Mughal authority, but on the contrary, instructions were issued that the Mughal emperor should be accorded "reverence and respect" so that the Company could participate in "the nominal authority of the Mughal."91All the trappings of the Mughal imperial authority structures were eventually adopted by the British colonial state to legitimize its rule in India. In any case, Tipu came to be branded as the ideal, typical "Oriental Despot," and this ideological construct eventually sank into the consciousness of the British population.

The name Tipu means "tiger" in the vernacular, and from the early 1790s and for more than thirty years after his death in 1799, the ruler of Mysore was accorded a curious cult status in Britain. He became "firmly embedded in nursery folklore" as the vicious, barbarous "oriental tiger the British loved to hate."92The British imagination was particularly exercised on account of the

well-publicized fact that Tipu owned a life-sized mechanical toy which comprised a tiger mauling a soldier of the EIC. After the defeat of Tipu, the toy tiger, which could be made to emit a wide range of snarls and screams, was taken to London and displayed in the India House in Leadenhall Street and became one of the popular sights of the city. 93According to Chris Bayly, alleged mistreatment of British prisoners of war by Tipu and overtures toward him by the French, which led to the Sultan planting a republican "liberty tree" and donning a cap of liberty, came as a gift to the propagandists.94The "opium eater" Thomas De Quincey among others was much exercised by the "oriental and barbaric paegentry" of the rulers of Mysore and by their "insane hatred" and "diabolic enmity" towards Britain.95In his numerous writings and pamphlets, De Quincey extolled the qualities of the "British bulldog" which was described as being far more courageous than the "Bengal tiger." After the death of Tipu in the battle of 1799, De Quincey was gratified to learn that the tiger's "unparalleled ferocity was settled by one thrust of a bayonet in the hands of an English soldier."96

As Denys Forrest97has documented, during the various phases of the Mysore war, first with Haider Ali and then with Tipu, a remarkable range of paintings, engravings, fiction, and plays depicting the military encounters had appeared in Britain. Popular prints portrayed the fall of Tipu's capital Seringapatam, and murals depicting the same event adorned the walls of Dublin's Lyceum Theatre.98The English painter J. W. Turner saw it fit to devote three large watercolors to the 1799 seige of Seringapatam. A play about Tipu was staged at Covent Garden in 1791, and the following year two more plays about him were staged at Astley's.99In 1823, another play, *Tippoo Saib, or the Storming of Seringapatam* was produced at the Royal Coubourg Theatre, and a version of this play was even marketed for use in toy theaters. The persona of Tipu had sunk so deeply into the consciousness of the people of England that a generation later, when Raja Ram Mohun Roy, the Bengali reformer, walked down the streets of Bristol, he was followed by groups of children screaming "Tipu, Tipu."100

On his part, Tipu represented his opposition to British expansionism in the language of the struggle between Islam and Christianity and actively sought allies outside India. In 1799 he wrote to the Ottoman sultan that the "infidels were a force of evil to all God's creatures" and that in the region of Bengal and other regions where their authority prevailed, "they set up swine butchers and cause them to sell the flesh of hogs publicly in the streets."101The French, aware of Tipu's need for allies outside Mysore, sought to create an alliance with him by deploying the rhetoric of liberty and *levee en masse*. In general, Tipu presented himself as an Islamic hero opposed both to "Mughal effeteness" and British tyranny.102This was reflected in his attempt at establishing himself as an "emperor" independent of Mughal authority, and his accentuation of the Islamic features of the state of Mysore during the period of conflict with the British.

The Fall of Seringapatam

In the Third War of Mysore of 1792, Tipu's light cavalry, dubbed "the best in the world" by Arthur Wellesley, had pressured Cornwallis' army to come to terms with Tipu and be satisfied with a partial victory. 103In the intervening seven years, Tipu had realized that the decline of Muslim-controlled trade in the Arabian Sea and the dramatic rise in the

Company's trading interests on the west coast presented a threat to all the Indian states of the region. Consequently, he attempted to stimulate trade with Arabia and Persia by setting up state trading institutions in the port towns. In the end, however, a number of structural changes that had occurred within the intervening years worked against the regime of Tipu. As Chris Bayly puts it, ultimately, Tipu and his armies attempted to face European mercantilist power with its own weapons, state monopoly and an aggressive ideology of expansion. However, he failed, not because Mysore represented a decaying eastern despotism but because the resources of the British were expanding much faster than those of Mysore, fueled both by Indian merchant capital and by European control over the most productive parts of the countryside.104Ultimately, the state of Mysore, which had been described by a British observer as "well cultivated, populous with industrious inhabitants, cities newly founded and commerce extending,"105that had begun to develop a capacity for the production of heavy artillery, and represented a major threat to the British, was conquered and brought under the latter's control. Tipu died fighting the army of the Company at the gates of Seringapatam, true to his adage, "better to live a day as a lion than a lifetime as a sheep." His young sons were taken as hostages by Lord Cornwallis.106A descendent of the pre-Muslim kings, Raja Krishnadevaraja III (17991836), was installed and the capital moved from Seringapatam to Mysore. Although a number of traditional cultural and religious symbols were actively deployed in an effort to invent tradition and to legitimize the idea that Tipu the tyrant had been deposed and authority restored to the legitimate heirs of the earlier Vijayanagara empire, actual control and administration of the province quickly passed and remained in the hands of the British.107

The Charter of 1813: Termination of Monopoly for the East India Company

Eventually, against the backdrop of the end of the Napoleonic Wars and pressures from the Lancashire manufacturers anxious for markets in India, the British government decided to increase its direct control over the Company. The new charter of 1813 ended all monopoly of the Company in India, provided for the separation of territorial and commercial accounts, and paved the

way for full colonial administration. By the end of the Napoleonic Wars, all hesitations and doubts about retaining India as a colony receded, and after 1820, "England never had any intention of parting either with her colonial trade or with the governance of India." 108

The above account of the consolidation of British colonial rule over particular regions of India is, of course, not definitive. Historians are by no means in agreement over the analytical sketch offered above. However, the purpose of this chapter has not been to embark on an intricate examination and evaluation of the various competing accounts and explanations of the British conquest of India. This chapter had the rather limited objective of sketching, in extremely broad strokes, the social, political, and economic context of the origins and consolidation of British colonial power in the Indian subcontinent.

The next chapter examines the complex social forces involved in the introduction of modern Western science and technology in colonial India. At about the same time that colonial power was being consolidated, spectacular strides were being made in the field of science and technology, both in Britain and on the continent. Thus the "scientific revolution" in seventeenth-century England occurred at about the same time as the establishment of colonial empires, and it would hardly be surprising to find some connection between the two events. In fact, as has been argued in this chapter, the early eighteenth-century British ban on the import of cotton textiles contributed significantly to the precipitation of the Industrial Revolution. However, despite a large volume of studies of various aspects of colonial rule in India, relatively little attention has been paid to the links among science, technology, and empire.109The chapters that follow address this significant but neglected issue in the understanding of the practice of science, the building of scientific institutions under colonialism, and its relevance for the particular trajectory taken by contemporary modes of scientific knowledge and technological innovation, not only in India but in Britain as well.

Notes

1. Tacitus, *Annals*, iii, 53. Cited in Wilferd H. Schoff, 1974: 219.

2. Cited in P. J. Thomas, 1926: 37.

3. Cited in Shafaat Ahmad Khan, 1923: 215.

4. Cited in Chandra Mukerji, 1983: 166.

5. For a good account of the earliest European travelers to India, see Boies Pensrose, 1967, chapter 5.

6. Mohammad Azhar Ansari, 1975: 1.

7. Ramkrishna Mukherjee, 1958: 62.

8. William Foster, 1921: 6.

9. For an abbreviated but fascinating firsthand account of the travels of Ralph Fitch as well as others during the mid-sixteenth century, see Samuel Purchas, 1905.

10. Thomas Roe, 1926 [1899]: xv.

11. *Ibid*.

12. *Ibid*., xvii.

13. R. C. Prasad, 1965: 100.

14. Roe, 1926: xviii.

15. *Ibid*.

16. *Ibid*., li.

17. *Ibid*.

18. The term "factories" referred to warehouses where export articles to Europe and other places were kept.

19. Roe, 1926: liv.

20. *Ibid*., xliii.

21. *Ibid*., 50405.

22. Janet Abu-Lughod, 1989: 264.

23. Schoff, 1974.

24. Abu-Lughod, 1989: 265.

25. The Madras Government Museum has a nearly complete series of coins of the Roman emperors during the period of active trade with India, all of them excavated in southern India. See Schoff, 1974: 21920 for further details. A good account of the maritime trade in the ancient period can be found in E. H. Warmington, 1974; Vimala Begley and Richard Daniel De Puma, 1991.

26. Pliny, vol. 6, 26, cited in Schoff, 1974: 19.

27. K. N. Chaudhuri, 1982: 382.

28. *Ibid*., 383.

29. *Ibid.*, 384.

30. *Ibid.*, 385.

31. Fernand Braudel, vol. 1, 1972: 546.

32. K. N. Chaudhuri, 1982: 387.

33. *Ibid.*, 392.

34. *Ibid.*, 390.

35. P. J. Marshall, 1987.

36. K. N. Chaudhuri, 1982: 394.

37. For this section, I draw on the following sources: P. J. Thomas, 1926; Alfred Plummer, 1972; S. B. Allen, 1958; and Mukerji, 1983.

38. P. J. Thomas, 1926: 38.

39. P. J. Thomas, 1926: 26.

40. Mukerji, 1983: 18896; P. J. Thomas, 1926: 2547.

41. P. J. Thomas, 1926: 27.

42. *Ibid*.

43. Lewis Roberts, quoted in Mukerji, 1983: 192.

44. All quotes are from P. J. Thomas, 1926: 3235.

45. Quoted in P. J. Thomas, 1926: 34.

46. Quoted in Thomas, 1926: 27.

47. P. J. Thomas, 1926: 27. A detailed account of the "calico craze" can be found in Shafaat Ahmad Khan, 1923.

48. P. J. Thomas, 1926: 152.

49. Cited in P. J. Thomas, 1926: 135.

50. Cited in Thomas, 1926: 145.

51. P. J. Thomas, 1926: 161.

52. E. J. Hobsbawm, 1968: 56.

53. Anupam Sen, 1982: 57.

54. Quoted in Romesh Dutt, vol. 1, 1969: 26263.

55. Karl Marx and Frederick Engels, 1976: 5152.

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56. Hobsbawm, 1968: 148.

57. See Morris, D. Morris et al., 1969.

58. Cited in Dutt, vol. 1, 1969: 262.

59. Cited in Dutt, vol. 2, 1969: 112.

60. Karl Marx, 1977: 471.

61. Immanuel Wallerstein, 1990.

62. There has been a fair amount of debate regarding the degree of centralization of the Mughal empire and whether the empire "collapsed" or declined rapidly over a relatively long period of time. The "Aligarh school," represented by Irfan Habib (see I. Habib, 1963) among others, argues for a highly centralized Mughal empire, which collapsed in the mid-eighteenth century. The "Cambridge school," represented by Chris Bayly and David Washbrook, has sought to revise the views of the historians of the Aligarh school. See C. Bayly, 1983, 1990; and D. Washbrook, 1988. However, the difference between these two schools is not quite as unbridgeable as has often been made out. For another view of the same issue, see Mujaffar Alam, 1986; Athar Ali, 1975.

63. Habib, 1963.

64. *Ibid.*, 31938.

65. Fernand Braudel, vol. 3, 1984: 512. For a good account of the armies in various regions and time periods in India, see Dirk H.A. Kolff, 1990.

66. Fernand Braudel, vol. 3, 1984: 513.

67. *Ibid.*, 515.

68. Habib, 1963: 346.

69. Bayly, 1990: 3.

70. *Ibid.*

71. *Ibid.*, 11.

72. *Ibid.*, 4851.

73. *Ibid.*, 50.

74. *Ibid.*

75. Washbrook, 1990: 479508.

76. Bayly, 1990: 53.

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77. Anthony Giddens, 1984. For a critical discussion see Zaheer Baber, 1991.

78. Bayly, 1990: 5.

79. Washbrook, 1988: 76.

80. K. N. Chaudhuri, 1978: 56.

81. Roe, 1926. Cited in Braudel, 1984: 493, 670.

82. Wallerstein, 1990: 32.

83. *Ibid.*

84. For a detailed account, which provides a French perspective of the Anglo-French rivalry in Bengal, see S. C. hill, 1903.

85. Cited in Wallerstein, 1990: 33.

86. Wallerstein, 1990: 32.

87. Percival Spear, cited in Wallerstein, 1990: 33.

88. Wallerstein, 1990: 33.

89. Bayly, 1990: 102.

90. *Ibid.*, 8182.

91. *Ibid.*, 82. In fact, as many social historians have pointed out, the Mughal imperial authority structure eventually became the model of the British colonial state. For an account of how this was achieved, see Bernard Cohn, 1983.

92. John Barell, 1991: 50.

93. It is now on display in the cafe of the Victoria and Albert Museum in London.

94. Bayly, 1989: 114.

95. Barell, 1991: 5051.

96. *Ibid.*, 51.

97. Denys Forrest, 1970.

98. Bayly, 1989: 114.

99. Barell, 1991: 50.

100. Bayly, 1989: 114.

101. *Ibid.*, 173.

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102. *Ibid.*

103. In the following two paragraphs, I rely on Bayly, 1990: 9799.

104. Bayly, 1990: 9798.

105. Edward Moore, 1794. Cited in Sen, 1977.

106. Bayly, 1990: 97.

107. *Ibid.*, 113.

108. Fay, cited in Wallerstein, 1990: 34.

109. See Deepak Kumar, 1991.

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Scientific Solutions for Colonial Problems

A Department for the systematic utilization of geographical work has been considered to be an important and indeed an essential element in the Home Government of a great Colonial Power, ever since Columbus first sailed from Palos. and the value of science in all branches of administration was as great, then as now. The story of the Great Trigonometrical Survey, when fitly told, will form one of the proudest pages in the history of English domination in the East.
C. Markham 1

The actual survey, upon geometrical principles, of a region containing above 40,000 square miles, generally of an extremely difficult surface, full of hills and wildernesses and never before explored by European science form altogether an achievment of extraordinary merit, adding most materially to the stores of Indian geography, and of information useful for military, financial, and commercial purposes.
Dispatch from the Court of Directors of the East India Company, 18102

Now that we are engaged either in wars, alliances, or negotiations, with all the principle powers of India, and have displayed the British standard from one end of it to the other, a map of Hindoostan, such as will explain the local circumstances of our political connections and the marches of our armies, cannot but be highly interesting to every person whose imagination has been struck by the splendour of our victories, or whose attention is aroused by the present critical state of affairs in that quarter of the globe.
James Rennell 3

When India can do her own engineering work and carry on her own industries, then, and only then will she be able to govern herself.
Alfred Chatterton4

As indicated earlier, social and political conditions prior to the consolidation of British power in India were in a state of flux, partly as a consequence of the social changes stimulated by the emerging world system around the circuits of international trade and commerce. This does not mean that India was in a state of total "chaos" or "anarchy," a favorite theme of the Victorian historians and colonial administrators, that was often used to justify and legitimize conquest and annexation of new Indian territory. For example, on the occasion of one such annexation, Governor-General Arthur Wellesley argued that the British government was "obliged to interfere in the internal administration in order to save the resources of the state."5Under such conditions of rapid social and political change, indigenous patronage for science and technology declined, and in some areas, disappeared totally. Moreover, with the emergence of British colonial rule, the conditions under which Jai Singh had attempted to acquaint himself with European science no longer prevailed. Hence, during the early phase of colonial rule, any further introduction of modern Western science and technology in India was initiated by individual colonial administrators, and later, the colonial state.

Following Shiv Visvanathan, the introduction of Western science and technology in India can be divided into three broad phases.6The first phase followed immediately after the British conquest or annexation of territories in India in the mid-eighteenth century. It was the era of the "great surveys," or a period that witnessed the execution of a wide range of topographical, statistical,

trigonometrical, cartographic, and other surveys. These early surveys, conducted on a "scientific" basis, had significant consequences not only for the development of science in India, but also for the development of scientific knowledge in Britain and Europe. Closely associated with the first phase was the establishment of the Asiatic Society of Bengal by William Jones in 1784, an event that contributed to the institutionalization of modern Western science in India. The second phase led to the introduction of scientific and technical education in colonial India. It was marked by recurring conflicts and the airing of competing views regarding the direction scientific and technical education should take in

colonial India. These conflicts led to the famous "Anglicist-Orientalist" controversy of 1835, which had significant consequences for the development of science and technology. Although the impact of this controversy has been somewhat exaggerated, its resolution contributed to the withdrawal of support for preexisting indigenous educational institutions, extension of patronage for scientific and technical instruction in English, and the establishment of universities in the presidency towns of Calcutta, Bombay, and Madras. The third and final phase consisted of systematic attempts by the colonial state to forge institutional links among science, technology, and the Indian economy. This led to numerous "experiments" in the development of scientific institutions in colonial India, experiments that had significant consequences for the evolution of science and technology as well as the development of Indian society.

This chapter addresses issues primarily related to the first phase by examining the complex social factors that shaped and influenced the introduction and development of modern science during early colonial rule in India. The main focus of the analysis will be on examining the manifold ways in which science and technology were intimately connected with the exercise and legitimation of colonial power and the development of the colonial state. A related focus of the chapter is the production of new scientific knowledge and institutions as a consequence of this intersection of scientific knowledge, technology, and colonial power.

From a Trading Company to a Colonial State: The Scientific Mapping and Measurement of New Imperial Possessions

After the Company gained formal rights to collect revenues for the areas of Bengal, Bihar, and Orissa, the issue of obtaining accurate information about the extent of the produce, the population, and other statistics about the area under their control acquired immediate significance. Although the process of the transformation of a trading company into a colonial state was gradual and not uncontested, the organized and detailed scientific surveys initiated in India

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in the second half of the eighteenth century, contributed significantly towards accomplishing this transition. In this process of colonial state formation, amateur scientists and the knowledge produced by their activities played a major role. This chapter explores this complex, mutually constitutive relationship between scientists and the colonial state.

While defining a state as "a human community that (successfully) claims the monopoly of the legitimate use of physical force within a given territory," Max Weber hastened to emphasize that "territory is one of the characteristics of the state." 7Weber's focus on the connection between clearly defined territorial boundaries and the exercise of state power has been explored further by S. N. Eisenstadt, who has underscored the role of the precise delineation of boundaries as constitutive of the "attempt to establish a unified, relatively homogenous rule over a given territory and a more or less clear definition of the frontiers of this territory."8In the context of colonial India, Ainslie Embree has extended this analysis to argue that the mapping and demarcation of clearly defined territorial boundaries was one of the key factors contributing to the transformation of a "trading company into a state."9

The attempt by the early colonial administrators to usurp the hegemony of the Mughal empire led to efforts at asserting direct administrative control over clearly defined territorial boundaries. The *farmans* (imperial orders) that transferred the *diwani* of Bengal to the EIC did not specify any boundaries of the provinces that came under its control. Soon after assuming formal control, the Company officials discovered that the existing rent rolls were reliable only for the internal settled districts, while the boundaries of the external districts were ambiguous and not at all clearly demarcated.10During the Mughal period, the external boundaries were in a constant state of flux, partly due to the expansionist nature of the empire, whose successive rulers never regarded the frontier as a fixed limit. The general Mughal practice of leaving border areas under the control of tributary chieftains constituted an arrangement that ensured the continuance of undefined frontier regions, and there was little interest in the demarcation of linear boundaries. The situation was similar for the Maratha kingdom in the eighteenth century, which was also characterized by rapid expansion and flexible frontiers. In practice, territorial sovereignty under the Mughals meant the ability to collect revenue and command the loyalty of local chieftains in times of war. Consequently, the precision of boundaries of the internal divisions of the Mughal empire, meticulously outlined and described in Abul Fazl's *Ain-i-Akbari* contrasted starkly with the vagueness and ambiguity of the external frontiers.11

Although this arrangement served until the early eighteenth century when the Bengal *nawabs* owned nominal fealty to the Mughal emperor in Delhi, the situation changed when the EIC literally replaced the *nawabs* and acquired the formal role of the *diwan* of Bengal and the allied *subas* (provinces) of Bihar and Orissa. In 1765, the Company *Bahadur* (literally,

the "brave" company),

took direct control of the collection and administration of the revenue of these provinces, which was estimated at over four million pounds. 12The acquisition and direct control of the revenue and monopolies of valuable produce such as indigo, saltpeter, betel nut, and salt required the delineation of clearly defined territorial administrative boundaries as a prelude to the assertion and maintenance of sovereignity. Such concerns led to the execution of detailed and well-organized surveys of the newly acquired territories in the attempt to specify boundaries, to render unknown areas visible, and to accumulate detailed knowledge about new imperial possessionsactivities that were indispensable for rational administration and the exercise of colonial power. The pressing need for organized surveys in the early phase of British colonial rule was best expressed by Clements Markham, a senior colonial administrator. Markham described the early maps of the areas under possession as "very innaccurate only of service while India was an unknown region. [These maps] ceased to be tolerable when that vast country became a British imperial possession, requiring to be administered."13

"The First Great English Geographer": Surveyor-General James Rennell and the Development of Scientific Geography

James Rennell arrived in India in 1760, barely three years after the Battle of Plassey, in the midst of the Anglo-French confrontation that led to the siege of Pondicherry. Interested in marine surveying, Rennell was employed by the navy. In the course of his naval expeditions, he executed extensive surveys of the coastal areas of southern India and Ceylon. According to one account, even on the voyage to India, Rennell, "without help or encouragement, [had] never missed an opportunity of surveying the ports in which the *America* anchored,"14and the potential usefulness of his expertise did not go unnoticed. Rennell's interest and expertise in surveying caught the attention of Vansittart, the governor of Bengal presidency, who was the "first British ruler in India who felt the importance of accurate surveys and was anxious to inaugurate some system for correcting and revising the received geography of Bengal."15

With patronage and support from Governor Vansittart and the EIC, the project of surveying Bengal was initiated by James Rennell in 1763, barely six years after the Battle of Plassey. Relying on the *Ain-i-Akbari*, the gazetter compiled during Akbar's reign, Rennell proceeded with tentatively fixing points along the course of the Ganges. Although the administrative, economic, and political significance of the initial survey was clear for the local administrators stationed in India, this was not often the case with the Court of Directors of the Company in London, who frowned on any expense that

seemed superfluous for what was primarily a trading company. Rennell, however, had strong support from Governor Vansittart who, before leaving for England after the completion of his term, reassured him: "As the work you are now employed on will, I think, be of great use, so nothing in my power shall be wanting to put your services in such a light to the Company that they may give you the encouragement that your diligence deserves." 16Vansittart was successful in persuading the Court of Directors of the strategic importance of the survey of Bengal, and Rennell was retained by the Company for the substantial allowance of a thousand pounds a year. The patronage extended by the Company enabled Rennell to extend his survey to cover the areas of Bihar and Orissa, right up to the foothills of the Himalayas.

When Robert Clive returned to India as governor of Calcutta in May 1765, he was well aware of the strategic and administrative importance of accurate surveys of the areas under the control of the Company. Before Clive had left England, the historian Robert Orme had urged him to "make a vast map of Bengal, in which not only the outlines of the province, but also the different subdivisions of Burdwan, Beerboom etc. may be justly marked. Take astronomical observations of longitude, if you have anybody capable of doing it."17As Rennell was the person most qualified to execute these tasks, Clive appointed him to the position of the first surveyor-general of Bengal. Clive provided Rennell with funds and a company of sepoys for "protection"18and wrote to the Court of Directors that "we have appointed Captain Rennell, a young man of distinguished merit to this branch, Surveyor-General and directed him to form a general chart."19Despite protests from some quarters, mainly at the expense being incurred due to the surveys, Clive managed to convince the Court of Directors of their economic and strategic importance.

Assured of continued patronage from the Company, Rennell proceeded to complete detailed surveys of Bengal, Bihar, Orissa, and parts of the Mughal empire, almost as far as Delhi. A complete chart of the Ganges, which constituted a vital channel for the movement of articles of trade and commerce, was prepared during the same period. In addition to the surveys and preparation of charts, Rennell conducted a number of studies in the then emerging field of physical geography and geology. Because of the importance of rivers for trade and commerce, the constant changes in their courses were of great concern, and Rennell made a number of observations regarding the sedimentation process, and the instances and possible causes for the change in courses of the Ganges and the Brahmapootra.20Rennell also prepared a very detailed and precise map of inland navigation routes, which in addition to its importance for transportation connected with trade, was significant from a military and strategic point of view.21As he observed:

> So equally and admirably diffused are those natural canals, over a country that approaches nearly to a perfect plane, that we may safely pronounce,

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> that every other part of the country, has even in the dry season, some navigable stream within 25 miles at farthest. All the salt, and a large proportion of the food, consumed by ten millions of people are conveyed by water. [T]o these must be added, the transport of the commercial exports and imports, probably to the amount of two million sterling *per annum*; the interchange of manufactures and products, throughout the whole country. In a military point of view, it opens a communication between the different posts, and serves in the capacity of a *military way* through the country; renders unnecessary the forming of magazines; and infinitely surpasses the celebrated inland navigation of North America, where the *carrying places* not only obstruct the progress of an army, but enable the adversary to determine his place and mode of attack with certainty (emphasis in the original). 22

By the mid-1770s, Rennell had compiled enough maps and charts to prepare the *Bengal Atlas* and the *Map of Hindoostan*. Assured of a pension of six hundred pounds by Warren Hastings, Clive's successor, the first surveyor-general of Bengal collected all his charts, drawings, and maps and set sail for England in March 1777.

First published in 1779, the *Bengal Atlas* was followed by a second edition in 1781. From the point of view of the colonial administrators based in Bengal, the significance of the publication of the *Bengal Atlas* cannot be overemphasized. It was the first modern atlas of the province, drawn on a scale of three miles to an inch, prepared after years of detailed mapping and fixing of positions through the use of innovative measurement techniques, like the measurement of distances by means of a perambulator, i.e., a large wheel fitted with a device for counting revolutions and directions by a magnetic compass. Geographical positions were determined by means of detailed astronomical observations.23The atlas, running into fourteen folios, of a province that constituted "the British Bridgehead,"24was deemed by Clements Markham as a "work of the first importance both for strategical and administrative purposes."25Keenly aware of the significant role of the various officers of the East India Company in patronizing his scientific interests, Rennell dedicated the *Bengal Atlas* to governors Robert Clive, Cartier, Warren Hastings, and other key administrators.

The Royal Society, Patronage, and Rennell's Map of Hindoostan

The publication of the *Bengal Atlas* attracted the attention of the scientific community of London and led to the immediate appointment of Rennell as a member of the Royal Society. This signalled his completion of the rite of passage from an amateur surveyor to a professional scientist. The Royal Society

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not only provided a conducive institutional setting and intellectual atmosphere for his later work on the geography of India, but also brought him in contact with its president, Joseph Banks, who was arguably the most influential and well-connected patron of science in eighteenth-century England. 26Banks, who has accompanied Captain Phipps to Newfoundland and had sailed with Captain Cook on his first voyage around the world, was an ardent supporter of botany and general science and took a personal interest in Rennell's extensive collection of charts and maps on India.

Banks's interest and the institutional support provided by the Royal Society enabled Rennell to begin planning the production of what he described as "a work much wanted at this time"a map of India.27The *Map of Hindoostan* (1782) and an accompanying volume of *Memoirs* (1783), appropriately dedicated to Joseph Banks, were described by Rennell as an attempt to "improve the geography of India and the neighbouring countries."28The *Memoir* and the *Map of Hindoostan* were republished in a number of editions, and the latter was judged by the scientific community to be one of the best scientific and cartographic products of the time. The publication of the *Map of Hindoostan* earned Rennell the Copley Medal of the Royal Society, the highest honor that could be conferred on a scientist at that time. Addressing the Royal Society on the occasion, Joseph Banks observed:

> I should rejoice could I say that the Britons, fond as they are of being considered by surrounding nations as taking the lead in scientific improvements, could boast a general map of their island as well executed as Major Rennell's delineation of Bengal and Bahar: a tract of country considerably larger in extent than the whole of Great Britain and Ireland but the accuracy of his particular surveys stands out yet unrivalled by the most laborious performance of the best country maps this nation has hitherto been able to produce.29

Rennell's Survey, Colonial Administration, and Scientific Discourse

Rennell's work had significant consequences for the consolidation of administrative power and expansion of colonial rule in India, as well as the development of scientific geography in Britain. An earlier map by D'Anville, *Carte de Inde*,30published in 1775, was based on rough military route maps and charts and was not as detailed or reliable as Rennell's map. By contrast, the *Map of Hindoostan* was based on extensive surveys and the use of modern cartographic techniques. The *Map of Hindoostan* provided the basis for much of the more organized trigonometrical, topographical, and revenue surveys conducted during the early phases of British rule in India. Rennell's accurate

delineation of the areas under British control and his meticulous mapping of the inland navigation routes proved to be indispensable for the emerging system of colonial administration in late eighteenth-century India. The usefulness of his pioneering survey work was recognized by the early colonial administrators like Clive and Hastings and was expressed well by Clements Markham, who emphasized the significance of the "utilization of geographical knowledge and the value of science in all branches of administration." 31Expressing the need for a "department for the systematic utilization of geographical work [that would constitute] an essential element in the Home Government of a great Colonial Power," Markham appreciated the value of Rennell's work by comparing it with maps produced earlier: "Such work was of course very innaccurate; and the maps of that period were only of service while India was an unknown region, to be traversed by armies, and ceased to be tolerable when that vast country became a British imperial possession, requiring to be administered."32Although Rennell's surveys of the territories under British control contributed to the development and refinement of the colonial administrative apparatus and the development of the colonial state, his work also contributed substantially to the emergent scientific discourse of geography and geology in nineteenth-century Europe. Indeed Rennell's work provides a good example of the mutually constitutive relationship between scientific knowledge and colonial power.

In the theoretical debates of the nineteenth century, geographers and geologists in Britain and continental Europe drew extensively on Rennell's work, especially his study of ocean currents, undertaken on his return voyage from India.33His paper, "An account of the Ganges and Burrampooter," read at a Royal Society Meeting in 1781, provided detailed analysis of the formation of the great deltas of the two rivers, the sedimentation process, and the factors involved in the changes in their courses.34His paper evoked considerable interest especially since a major scientific controversy of the period revolved around the exact nature of river deltas, the sedimentation process, its impact on river courses, and the possibility of formulating general laws for these natural phenomena.

In the late eighteenth-century when attempts were underway to formulate general ahistorical laws in the emerging field of geology, Rennell's data from India provided fuel for scientists who took diametrically opposite positions on the issue. James Hutton, recognized as one of the founders of modern geology35relied heavily on Rennell's work to support his general theory of the transport of material and sedimentation in rivers in his *Theory of the Earth, with Proofs and Illustration*, published in 1795. In formulating a general law for the sedimentation process in rivers, Hutton argued that "the same operation is transacted everywhere; it is seen upon the plains of Indostan, as in the Haughs of Scotland; the Ganges operates upon its banks and is employed in changing its bed continually as well as the Tweed."36Exemplifying

what philosophers and

sociologists of science have termed the underdetermination of theories by facts, the same data presented in Rennell's paper were utilized by Richard Kirwan, another eminent eighteenth-century geologist, to refute James Hutton's argument. In his *Geological Essays* (1799), Kirwan argued that "rivers do not carry into the sea the spoils which they bring from the land, but empty them in the formation of deltas of low alluvial land at their mouths according to what Major Rennell has proved." 37Further exemplifying the conflict of interpretation arising from the same data, yet another geologist, John Playfair, utilized Rennell's data to defend Hutton against Richard Kirwan's criticisms. In his book *Illustrations of the Huttonian Theory* (1802), Playfair contended:

> The fact of the formation of deltas from spoils which the rivers carry from the higher grounds, is perfectly ascertained; and the detail into which Mr. Rennell has entered in the passage referred to by Mr. Kirwan does credit to the acuteness and accuracy of the excellent geographer. But it was not there asserted that rivers employ *all* the materials which they carry with them, in the formation of those deltas, and deliver none of them into the sea. On the contrary they carry, from the *delta* itself mud and earth, which they can deposite nowhere but in the sea.38

In addition to their use in the above controversy, Rennell's data from India were also used by other eminent geologists of the period. A full chapter on the erosion of land surface by rivers in C. Lyell's *Principles of Geology* (1830) was based exclusively on Rennell's observations, and H. T. de la Beche, while discussing the same issue in his *Geological Manual* (1831), argued: "Major Rennell described this delta [of the Ganges] in 1781, so that probably since this account was written very little material changes have been effected; yet as all these changes are likely to have been made in the same manner, Major Rennell's description will always be valuable, as showing the mode in which they have been carried on."39The impact of Rennell's contibution to the scientific discourse in England can be gauged from the fact that his observation of ocean currents led to the identification and study of what came to be known as "Rennell's Current."40The existence of this particular current, long suspected to be the cause of a number of navigational mishaps, was finally confirmed by Rennell, who also charted alternate routes for the navigation of ships. His work on ocean currents attracted the attention of Baron Humboldt, one of the leading scientists on the continent, who visited London from Paris in 1827 expressly to discuss the issue with Rennell.41Humboldt's work on the ocean currents of the North Atlantic, *Voyage aux Regions Equinoxiales du Noveau Continent* (18141825) drew heavily on what he called Rennell's "great hydrographic work."42Finally, a number of general works on geography and geology, ranging from Carl Ritter's *Die Erkunde im verhaltnisz Natur und zur Geschichte des Menschen* to C. Malte-Brun's *Precis de la Geographie Universelle* incorporated the Rennell's findings as outlined in his *Memoir*.43

Exemplifying what Chandra Mukerji 44has termed the "complex social embeddedness and autonomy of scientific thinking," Rennell's work, patronized by the East India Company and later the Royal Society, contributed simultaneously to the consolidation and expansion of British colonial power in India and to the emergent scientific discourse of geography and geology in eighteenth-century Europe. Of course, the theoretical debates themselves were embedded in the larger social context of issues such as the problems encountered during the course of maritime and inland navigation. However, the current obsession of some sociologists of science like Steve Woolgar45to reduce science simply to the social context or politics seems far-fetched and does not allow, to use a term from another context, for any "relative autonomy" to scientific discourse. The above discussion of Rennell's work illustrates the complex relationship between scientific discourse and social factors, and the problems associated with reducing one to the other.

Ironically, while Rennell's *Map of Hindoostan* contributed to the expansion of the territories under British control, its very success rendered it obsolete as far as administrative requirements were concerned. Aware of the limited usefulness of his map as far as the outer boundaries of the British-controlled territories were concerned, Rennell modestly noted that he had "only the merit of furnishing a dim light by which others groped their way."46Nevertheless, long after the British empire had expanded substantially, *The Map of Hindoostan* continued to provide administrators with accurate and detailed knowledge about the areas covered by it and remained an important work of reference for the more organized

surveys that were to follow later.

Military Campaigns, Surveys, and Soldier-Engineers

Rennell's work in Bengal had already demonstrated the strategic and administrative usefulness of accurate surveys to the early colonial administrators, and this perception was further reinforced by Colin Mackenzie's six-year survey (17921799) of the Deccan region, then formally under the rule of the *nizam* of Hyderabad. Convinced that the Deccan region was a "*terra incognita* of which no authentic account existed," except some "uncertain notices and mutilated sketches which by no means possess that philosophical accuracy demanded in modern times,"47Colin Mackenzie had surveyed the area and submitted a general map to the government of Madras presidency. The value of the map was immediately recognized by the governor-general of Madras presidency who noted that "the surveys of Captain Mackenzie appear to be of particular and immediate importance in a political as well as military point of view to the Command-Officer of the Detachment at Hyderabad."48The

observations of the governor-general proved to be prescient. A few months later, the *nizam* of Hyderabad enlisted some French officers in his army, which, according to the British, signified a growing influence of the French over the *nizam*. Mackenzie's map and expertise as a surveyor were utilized in a concerted and successful military action designed to force the *nizam* into submission and transform his dominion into a semi-independent princely state under the control of the EIC.

With the expansion of territories under British control, the strategic and administrative significance of scientific surveys became more evident to the colonial administrators. In numerous military campaigns, a number of "soldier-engineers" who were amateur surveyors and astronomy enthusiasts played key roles in planning and executing particular maneuvers by ascertaining distances between towns and by fixing positions of places through astronomical observations. Defined by a popular magazine of the period as "an able expert, who by a perfect knowledge in mathematics, delineates upon paper or marks upon the ground all sorts of forts and works proper for offence and defence," 49the "soldier-engineers" were able to utilize their expertise in survey techniques and other military skills in the repeated war campaigns against Tipu Sultan of Mysore. Two of the most prominent "soldier-engineers" who played active roles in the Mysore Wars were Captain Colin Mackenzie and Major William Lambton. The *Madras Courier* of November 3, 1799 had noted that "Mackenzie in his department had demonstrated by his success in pursuing the object, how essentially necessary it is that the practical engineer should unite art with science."50According to Colonel Gent, William Lambton "was particularly distinguished on several occasions, and his skill in fixing on a proper spot for an enfilading battery at Seringapatam was eminently conspicuous."51

The Mysore Surveys of Mackenzie, Lambton, and Buchanan

With the fall of Tipu Sultan, a vast tract of extremely prosperous territory with a large population passed swiftly under British control. The newly acquired territories and population had to be administered, governed, and, more importantly, accurately assessed for their revenue potential. The need for obtaining accurate and detailed knowledge about the new territory and population led to the inception of extensive and organized trigonometrical, topographical, revenue and statistical surveys of the state of Mysore. Barely a few months after the fall of Seringapatam, William Lambton and Colin Mackenzie made proposals for organizing the trigonometrical and topographical surveys, respectively, and were offered immediate assistance from Governor-General Arthur Wellesley and the government of Madras presidency.

Earlier experience and the usefulness of accurate survey charts and maps had convinced the British administrators of the vital necessity of setting up these operations on a larger scale. As Mackenzie recounted in a letter to a friend in 1817, "[Lord Wellesley] being justly of the opinion that a more complete knowledge of these countries was indispensably necessary for the information of government, was pleased, in the most handsome manner, to appoint me to survey Mysore." For his part, Mackenzie was convinced that "a complete survey of Mysore and its dependencies would be beneficial and satisfactory to Government." 52Accordingly, Mackenzie and Lambton were appointed to head the

topographical and trigonometrical surveys, respectively, while Francis Buchanan, an M.D. from Edinburgh University and an amateur but accomplished botanist, was appointed to conduct a botanical and statistical survey.

The trigonometrical, topographical, and statistical surveys complemented one another. The purpose of the trigonometrical survey was to fix the position of towns, villages and other landmarks which were plotted out on maps filled up later by topographical and statistical surveyors. Using the Madras Observatory as a fixed point of departure, detailed astronomical observations were undertaken for the determination of positions. The execution of the trigonometrical survey in Mysore led to the introduction of new techniques and instruments of measurement like the theodolite, a zenith sector and steel chains that contributed to greater accuracy.

Colin Mackenzie's surveys produced maps that were scaled an inch to the mile and showed every village, road, and tank in the province of Mysore.53Similar results were obtained from the surveys conducted by Lambton and Buchanan. Buchanan's statistical and botanical surveys resulted in the publication of the three-volume *A Journey from Madras Through the Countries of Mysore, Canara and Malabar*,54which added considerably to the store of knowledge about previously uncharted territory. All of these surveys contributed to the accumulation of knowledge vital to the formulation of administrative strategies and policies.

Buchanan received orders from Fort William instructing him to conduct a detailed survey of the region of Mysore on February 24, 1800, only a few months after the defeat of Tipu Sultan. The order, drawn up by Lord Wellesley himself, conveys a good idea of the systematic and comprehensive nature of the survey as well as the economic and administrative concerns that informed the project. According to Wellesley's instructions:

> Your inquiries are to extend thoughout the dominions of the present Raja of Mysore and the country acquired by the Company in the late war from the Sultan. The first great and essential object of your attention should be, the agriculture of the country. The next immediate object of your attention should be those natural productions of the country, which are made use of in arts, manufactures of medicines and particularly those which are

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> objects of external commerce. Mines and Quarries as objects of particular concern, you should make a subject of more minute investigation in so far as it relates to their produce. The study of the manufactures is a further object of consequence especially of those which are exported; you should, therefore, produce as exact an account of the different kinds as may be practicable. You should also make it an object of particular attention to ascertain how far the introduction of any of the manufactures of Mysore into any other of the Company's possession, might be productive of advantage, and respectively where Mysore might derive advantage from the importation of the growth, produce, or manufacture of Bengal or any other parts of the Company's possession. You will take every opportunity of forwarding to the Company whatever useful or rare and various plants and statistics you will be able to acquire in the progress of your researches with such observations on their nature as may be necessary. 55

Buchanan's expertise as a botanist and more generally as a natural historian was one of the reasons Lord Wellesley appointed him as the surveyor of the natural history and "statistics" of Mysore. However, in addition to facilitating the colonial administration through the accumulation of relevant knowledge, Buchanan's surveys also played a vital political role in mediating the developing conflict between the colonial administrators stationed in India and the Court of Directors in London. Up until the late eighteenth century, the Court of Directors of the EIC did not generally approve of further expansion and military conquests. Territorial administration was seen as inconsistent with the operations of a trading company and some influential directors had specifically opposed the war against Tipu Sultan.56In this regard, Lord Wellesley had attempted to impress upon the British the great significance of the war against Tipu by arguing that the destruction of the Mysore regime was as important as any of the wars the British were fighting in Egypt at that time.57By commissioning Francis Buchanan to survey Mysore, Lord Wellesley sought to prove to his opponents in London that Mysore was a prosperous province and worthy of conquest.

Buchanan's survey reports met Wellesley's expectations. Tipu and his regime were presented in an extremely negative light. Tipu was variously described as a despotic destroyer of dockyards, international commerce, palm trees, and pepper vines who "kidnapped or resettled labour in order to control a noncompliant people."58Where Buchanan found concrete evidence of extensive technological development in Mysore, he ridiculed and dismissed it as the "hopeless gropings of a despot whose authoritarian decrees betrayed a total ignorance of what genuine modernization required."59More

significantly, as far as the Court of Directors was concerned, Buchanan's report highlighted the high revenue-paying capacity of the peasantry in Mysore, which proved to be much greater than the Company had been led to believe from earlier estimates. Buchanan devoted a section of his report to the methods used by peasants in

avoiding taxation by understating the volume of production. Thus, Buchanan's report not only helped Wellesley ward off criticisms of expansionist policies by legitimizing the war against an Oriental despot 60but also underlined the possibility of increasing revenue sources through taxation. Buchanan's reports of his surveys fulfilled a multiplicity of objectives and interests, including his own as a botanist.

From Buchanan's perspective, the patronage extended by the Company for his survey, afforded him the opportunity of engaging in his botanical pursuits. Prior to his appointment as the surveyor of Mysore, Buchanan had joined the EIC as a medical officer. However, botany, which he described as his "hobby," remained his primary interest. The chance to survey Mysore was a welcome opportunity for him, and throughout his surveys, botanical pursuits consumed a large part of his time and energy. He knew that he could pursue his botanical work as long as he could draw the attention of the Company to the possible economic value of the plants in the region he surveyed. In this context, he managed to increase his botanical collection, providing a Linnean taxonomy to all of the plants he encountered during the survey. After returning to England in 1805, his collection was utilized extensively by James Smith, an eminent botanist, who was then in the process of publishing a volume titled *Exotic Botany*. As a result, Buchanan's botanical expertise was acknowledged in England, and, based on his botanical work in India, he was appointed a fellow of the Royal Society in May 1806.61A year later, Buchanan returned to India to conduct the Bengal survey, which occupied him for seven years between 18071814. Once again, he was determined "to mould the Bengal survey to suit his personal interest as he searched for regions which were less populated and therefore of greater botanical interest."62In due course, Buchanan's natural history collection became so bulky that he could not afford to ship it to England. On his retirement, he offered the entire collection to the EICan act he described as "throwing pearls before swine"in exchange for free transport.63Despite the fact that the relationship between him and the Company turned sour toward the end, the Company's patronage had enabled Buchanan to increase his botanical knowledge and to prepare extensive botanical drawings of a region that had been described by another eminent botanist of the time, Sir Joseph Dalton Hooker, as "more varied than that of any other country in the eastern hemisphere, if not the globe."64

Buchanan devoted over twenty years to botanical and natural history research in India, and his work led to the publication of a number of papers and books on Indian botany and natural history.65After returning to England, he spent most of his time on botany. In 1820, he wrote to his botanist friend, James Smith "what appears to me most likely to be useful to science would be to publish a commentary on the *Hortus Malabaricus* and *Flora Amboinensis*," both being works of an earlier generation of European botanists working in India.66Buchanan spent the next five years interpreting van Rheed's *Flora*

Malabaricus and published a number of papers in the scientific journals of his time. Buchanan's extensive botanical surveys and detailed commentaries on several species continue to be the subject of investigation and study in a number of research universities. 67

On the whole, although Buchanan used the surveys to pursue his botanical and scientific interests, the statistical details of Mysore and the topographical maps of many districts of Bengal procured as a result of his surveys provided the early colonial administrators with a wealth of knowledge useful for the administration and governance of the newly acquired territories. In particular, his detailed topographic maps of Bengal improved upon James Rennell's earlier *Bengal Atlas*, a fact that "must have pleased a Government which faced an escalating problem of public disorder and lawlessness" in those regions.68

Surveys, Scientific Knowledge, and Colonial Administration

As indicated earlier, during the early period of colonial rule, the governor-generals stationed in India had a difficult time

convincing the Court of Directors of the usefulness of the surveys. However, as the area under the Company's control expanded, the latter came to realize the importance of having accurate maps and accurate knowledge of the revenue potential and productive resources of the area under their control. In an 1810 dispatch to Fort St. George (Madras), the Court of Directors noted:

> The actual survey, upon geometrical principles, of a region containing above 40,000 square miles, generally of an extremely difficult surface, full of hills and wildernesses and never before explored by European science form altogether an achievment of extraordinary merit, adding most materially to the stores of Indian geography, and of information useful for military, financial, and commercial purposes.69

The projects initiated by the EIC in the late eighteenth century, led to the institutionalization of several organizations devoted to specific surveys on a scientific basis. On the one hand, the activities of organized surveyors facilitated the process of the rationalization of the colonial administration and the reflexive refinement of techniques of governance. On the other hand, they contributed to the transformation of British perceptions about India, which had until then been conceived of as a nebulous entity, defined primarily in cultural terms. The ongoing surveys contributed to the reconstitution of India as a geographically defined region with precisely demarcated boundaries. One of the crucial steps that led to the process of the constitution of India as a rational modern nation state was the Interpretation Act passed by the British Parliament in

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1889. According to this act, "The expression "India" shall mean British India, together whith any territories of any native prince or chief under the suzerainty of Her Majesty, exercized under the Governor-General, or through any Governor or other officer subordinate to the Governor-General of India." 70The Act of 1889 reflected the ability of an imperial power, supported by the institutional changes that had occurred in the preceding years, to define "India" as "British India." As should be evident from the discussion above, a whole range of scientists played a significant role, both in the complex social processes leading up to the Act of 1889, and in the more organized scientific surveys that would delineate the boundaries of the emergent modern nation state of India.

Some commentators have argued that "the early scientific work in India was practically amateur work done in their spare time by medical men who were interested in science."71While it is true that most of the figures discussed above were not really professional scientists in the strict sense of the term, such an argument ignores the fact that "science" was barely in the process of constituting a clearly defined professional domain in late eighteenth-century Europe. In fact "professional" scientists, as the term is understood today, were practically nonexistent in Europe until the mid-nineteenth century, even though there were a number of centers where substantial scientific research was being conducted by dedicated amateurs who worked within specific paradigms and traditions. The scientists in India were very much part of the tradition emanating from Europe, and their early surveys were guided by existing scientific paradigms. The Humboldtian paradigm, for instance, entailed the discovery of quantitative mathematical interrelationships and laws that were often represented on charts and graphs, and it involved the study of astronomy, physics, and geology from a geographical standpoint.72As mentioned earlier, Baron Humboldt had made it a point to meet and consult with James Rennell on his return to England from India. In this context, most of the early surveyors in India, including James Rennell, Colin Mackenzie, and William Lambert, were "not amateurs [but were] eagerly participating in the latest wave of international scientific activity."73In fact, the surveyors were influenced by certain changes in the general orientation of scientific knowledge in Europe that were linked to the growth of interest in social statistics and collection of detailed information about the population and physical features of the land. As Chris Bayly has pointed out, this was a period when eighteenth-century European concerns with "belief and system of value gave way to the empirical documentation of known facts."74It was this reorientation in scientific thinking that was reflected in the surveys conducted in India. Of course such reorientation was a development intimately associated with the emergence of the modern nation state wherein, in Michel Foucault's words, "the population is the object that government must take into account in all its observations and *savoir*, in order to be able to govern effectively in a rational and conscious manner."75E. J.

Hobsbawm's emphasis on the "element of artefact, invention and social engineering which enters into the making of

nations," 76was at work in the surveys that continued throughout nineteenth-century India and reflected a combination of shifts in the orientation of scientific knowledge as well as changes in the material and practical administrative requirements of a colonial state in the making. The surveys of colonial India led to the refinement of administrative techniques and rationalization of colonial power, to the exploitation of natural resources, and to the accumulation and emergence of new scientific knowledge as a consequence of the colonial encounter.

Sir William Jones, the Asiatic Society of Bengal, and Scientific Research in Colonial India

At about the same time that plans for the early surveys were being proposed in colonial India, William Jones, a judge at the Supreme Court of Calcutta, was contemplating setting up the Asiatic Society of Bengal. Modelled explicitly on the Royal Society of London, the Asiatic Society was inaugurated by Jones on January 15, 1784 in Calcutta at a gathering of thirty senior officers of the EIC. In setting up the society, Jones hoped that in due course it would "advance to maturity as the Royal Society, which at first was only a meeting of a few literary friends at Oxford, rose gradually to that splendid zenith, at which a Halley was their secretary, and a Newton their president."77As Jones recounted in his first "discourse" as the president of the Asiatic Society, it was an "inexpressible pleasure to find myself in the midst of so noble an amphitheatre [i.e., India], almost encircled by the vast regions of Asia, which has ever been esteemed the nurse of sciences, the inventress of delightful and useful arts."78

The specific objectives of the newly founded society were spelled out by Jones in the following terms:

> If now it be asked, what are the intended objects of our inquiries within these spacious limits [of Asia], we answer, MAN and NATURE; whatever is performed by the one, or produced by the other. [Y]ou will investigate whatever is rare in the stupendous fabrick of nature, will correct the geography of Asia by new observations and discoveries; will trace the annals, and even traditions, of those nations, who from time to time have peopled or desolated it. [Y]ou will examine their improvements and methods in arithmetick and geometry, in trigonometry, mensuration, mechanicks, opticks, astronomy, and general physicks; their systems of morality, grammar, rhetorick, and dialectick; their skill in chirurgery and medicine, and their advancement, whatever it may be, in anatomy and chemistry.79

The emphasis on "Man and Nature" echoed Thomas Sprat's original design for the Royal Society for recording "all the works of Nature or Art which can

come within their reach." 80Being a polyglot scholar, Jones emphasized learning Asian languages, "the diversity and difficulty of which are a sad obstacle to the progress of useful knowledge. [T]he attainment of them is, however, indispensably necessary [as] an immense mine would then be open, in which we might labour with equal delight and advantage."81

Following the plan of the Royal Society of London, "of which the King is Patron,"82William Jones and twelve other founding members solicited the support of the governor-general, Warren Hastings, who declined the invitation to be the first president of the society as he did not have "the leisure requisite to discharge the functions of such a station." Hastings, however, accepted the position of a patron because of "an early conviction of the utility of the institution" and promised to ensure "by whatever means the success of it."83Subsequently, Jones was nominated the first president of the Asiatic Society and proposed that members of the society assemble for "weekly evening meetings for the purpose of hearing original papers read on such subjects as fall within the circle of our inquiries."

The role of the Asiatic Society in propagating and institutionalizing modern scientific research in late eighteenth-century India has been overlooked by existing analyses of the society. William Jones is known primarily for his inculcation and patronage of research into the languages, literature, and philosophy of India. He has been credited with "the discovery of India's past,"84for waving "the golden wand that slowly made us shake off the sleep of ages,"85or, in the words of Nehru, "for the rediscovery of her [India's] past literature."86There is no doubt that the work of Jones and other orientalists like H. T. Colebrooke, James Prinsep, and H. H. Wilson contributed to the translation and interpretation of a number of classical Indian works of literature and law digests. It is equally true that the Asiatic Society played a significant role in stimulating research on the literatures and languages and in training a number of scholars versed in Indian languages. However, as Bernard S. Cohn has demonstrated, there was an intricate connection between the exercise

of colonial power and the accumulation of literary knowledge and linguistic competence.87Most importantly, as shown in the discussion below, the acquisition of the languages and literatures of India was perceived by Jones to be an essential component for investigating indigenous scientific knowledge. In this context, the literary researches of the "Orientalist" scholars complemented scientific investigations in colonial India. The society provided a conducive institutional setting for the informal discussion of scientific explorations undertaken by the Company's employees. The inauguration of the publication of the society's journal, *Asiatic Researches*, in 1788 provided a formal channel for the communication of the results of such scientific exploration and research.

On his way to India, Jones had compiled a list titled "Objects of Enquiry during My Residence in Asia." The list contained sixteen fields of study, including "The laws of the Hindus and Mahomedans," "arithmetic and geometry

and mixed sciences of Asiatics," "medicine, chemistry, surgery, and anatomy of the Indians," "Mughal administration," and "best mode of governing Bengal." 88The extensive list was typical of a rigorous scholar, as "no ordinary mortal would even think of achieving all this in a single lifetime."89But then, William Jones was no ordinary scholar. By the time of his death in 1794 at the age of forty-eight, he had acquired twenty-eight languages, believing that languages held the key to "the history of the human mind."90As the other members of the society were to realize, Jones's emphasis on the cultivation of linguistic skills proved to be immensely useful for investigating the indigenous modes of scientific knowledge and classificatory systems.

Shiv Visvanathan has correctly pointed out that "the institutionalization of Western science in India commences for all practical purposes with the establishment of the Asiatic Society of Bengal."91William Jones's annual "anniversary discourses," which represented stock-taking as well as agenda-setting for the coming year, constitute good documentary sources for understanding the institutional aims and goals of the society. As cited above, the first annual discourse provided a very general statement of objectives of the society. The subsequent anniversary discourses outlined clearly Jones's imperial assumptions as well as the connections among literary researches, linguistic skills, and investigation of indigenous sciences. Contending that "on the whole reason and taste are the grand prerogatives of European minds, while the Asiaticks have soared to loftier heights in the sphere of imagination," Jones argued:

> The civil history of their vast empires, and of India in particular, must be highly interesting to our common country: *but we have a still nearer interest in knowing all former modes of ruling these inestimable provinces, on the prosperity of which so much of our national welfare, and individual benefit, seems to depend*. A minute geographical knowledge, not only of Bengal and Bahar, but, for evident reasons, of all kingdoms bordering on them, is closely connected with an account of their many revolutions: but the natural productions of these territories, especially in the vegetable and mineral systems, are momentous objects of research to an imperial, but, which is a character of equal dignity, a commercial people.92

The emphasis on research on the "civil history" of India to ascertain "all former modes of ruling" was entirely consistent with the earlier agenda of inquiring into the "best mode of ruling Bengal" that Jones had sketched out en route to India. According to him, to embark on a thorough enquiry into the "civil history," "we seem to possess only four general media of satisfying our curiosity concerning it; namely, first, their *Languages* and *Letters*; secondly, their *Philosophy* and *Religion*; thirdly, the actual remains of their old *Sculpture* and *Architecture*; and fourthly, the written memorials of their *Sciences* and *Arts*."93Thus, knowledge of Indian languages and letters had to be acquired for a better understanding of former modes of governance, as well as the "written memorials" of Indian sciences.

Writing in 1785, Jones felt that "on the sciences, properly so named in which it must be admitted that the Asiaticks, if compared with our western nations, are mere children," and while conceding that "there may, indeed, have been, in the favourable atmosphere of Asia, some diligent observers of the celestial bodies," he cautioned the members of the society "not to expect any new methods, or the analysis of new curves from the geometricians of India." 94Just a year later, Jones was convinced that "what their astronomical and mathematical writings contain, will not, I trust, remain long a secret: they are easily procured, and their importance cannot be doubted."95By 1790, after the publication of Samuel

Davis' paper "Astronomical Computations of the Hindus," and Reuben Burrow's "A Proof that the Hindus had the Binomial Theorem" in the second volume of *Asiatic Researches*, Jones invoked Archimedes to assert, "Give us time, we may say, for our investigations, and we will transfer to Europe all the sciences, arts, and literatures of Asia."96

A thorough and extensive investigation of the sciences, technical crafts, and medicine of India required expert knowledge of classical Indian languages. Discussing "medical skills" that were "highly prized by the ancient Indians" and recorded in a number of texts, Jones contended: "What their old books contain on this subject, we ought certainly to discover, and that without loss of time; lest the venerable, but abstruse, language, in which they are composed, should cease to be perfectly intelligible, even to the best educated natives, through a want of powerful invitation to study it."97

Connected closely with the issue of medicine was the question of botanical identification of plants and herbs in use for pharmacological purposes. Jones, an accomplished amateur botanist who had worked closely with Johan Gerard Koenig, a student of Carl Linneaus, realized the significance of a knowledge of Sanskrit for better understanding the medicinal value of these plants as it was outlined in a number of texts. In his outline for a "Treatise on the Plants of India," he observed,

> Some hundreds of plants, which are yet imperfectly known to European botanists, and with the virtues of which they are wholly unacquainted, grow wild on the plains and the forests of India: the *Amarcosh*, an excellent vocabulary of the Sanscrit language, contains in one chapter the names of about three hundred medicinal vegetables; the Medini may comprize many more; and the *Dravyabhidhana*, or Dictionary of Natural Productions, includes, I believe, a far greater number; the properties of which are distinctly related in medical tracts of approved authority. Now the first step, in compiling a treatise on the plants of India, should be to write their true names in Roman letters, according to the most accurate orthography, and in Sanskrit preferably to any vulgar dialect; because a learned language is fixed in books, while popular idioms are in constant fluctuation, and will not perhaps be understood a century hence by the inhabitants of these Indian territories, whom future botanists may consult on the common appellations of trees and flowers.98

In planning the treatise, Jones's main purpose was to reduce the various indigenous classificatory systems to a modern taxonomical scheme based on the Linnean "natural order" of genera and species. As he put it,

> As we learn a new language, by reading approved compositions in it with the aid of a Grammar and Dictionary, so we can only study with effect the natural history of a vegetables by analysing the plants themselves with the *Philosophia Botanica*, which is the grammar, and the *Genera et Species Planatarum*, which may be considered as the Dictionary of that beautiful language in which Nature would teach us what plants we must avoid as noxious, and what we must cultivate as salutary, for that the qualities of plants are in some degree connected with the natural orders and classes of them, a number of instances would abundantly prove. 99

Although Jones was familiar with Linnaeus' classificatory scheme, which he described as "the system of Nature," he proposed to make certain changes in the taxonomical principles while classifying Indian plants. His major objection to certain "Linnaean appellations," was the Swedish taxonomist's reliance on the reproductive organs of flowers as the major classificatory principle. Jones objected to such a classificatory principle because,

> The allegory of sexes and nupitals, even if it were complete, ought, I think, to be discarded, as unbecoming the gravity of men, who, while they search for truth, have no business to inflame their imaginations: and, while they profess to give descriptions, have nothing to do with metaphors. Few passages in *Aloisia*, the most impudent book ever composed by man, are more wantonly indecent than the hundred and forty sixth number of the *Botanical Philosophy*, and the broad comment of its grave author, who dares, like Octavius in his epigram, to speak within Roman simplicity; nor can the Linnean description of *Arum*, and many other plants, be read in English, without exciting ideas which the occasion does not require. Hence it is, that no well born and educated woman can be advised to amuse herself with botany, as it is now explained.100

Jones's objective of reducing the "complexities" of the prevailing indigenous classificatory schemes into a single taxonomical system, an activity described by a critic in a different context as attaching "barbarous binomials to dried foreign weeds,"101required knowledge of Sanskrit. The classification of plants was important because

when the Sanscrit names of the Indian plants have been correctly written in a large paper book, one page being appropriated to each, the fresh plants themselves, procured in their respective seasons, must be concisely, but accurately, classed and described; after which their several uses in medicine, diet, or manufactures, may be collected, with the assistance of Hindu physicians, from the medical books in Sanscrit, and their accounts either disproved or established by repeated experiments, as fast as they can be made with exactness.102

Jones lamented the fact that although a number of European botanists like Van Rheede, William Roxburgh, and John Gerard Koenig had investigated the plants of some regions of India," none of those naturalists were deeply versed in the literature of the several countries from which their vegetable treasures had been procured; and the numerous works in Sanscrit on medical substances, and chiefly on plants, have never been inspected, or never at least understood, by any European attached to the study of nature." 103He reiterated the familiar theme of the significance of inculcating classical Indian languages:

Unless we can discover the Sanscrit names of all celebrated vegetables, we shall neither comprehend the allusions which Indian Poets perpetually make to them, nor (what is far worse) be able to find accounts of their tried virtues in the writings of Indian physicians; and (what is worst of all) we shall miss an opportunity, which never again may present itself for the Pandits themselves have almost wholly forgotten their ancient appellations of particular plants."104

In fact Jones had already begun the arduous task of compiling a list of botanical names alluded to in classical Indian poetical and medical compositions.

Knowledge of Sanskrit and other Indian languages was important not only for inquiring into the state of medicine and botany but also for other technical innovations of medieval India of use to the EIC. One of the technical innovations that had made Indian textiles popular on the international market was the development of permanent dyes that could withstand repeated washings. At that time, British textile manufacturers were unsuccessfully attempting to develop similar techniques, and as Jones emphasized in the "Second Anniversary Discourse" in 1785,

The sublime science of Chymistry (sic), which I was on the point of calling divine, must be added, as a key to the richest treasuries of nature; and it is impossible to foresee how greatly it may improve our manufactures, especially if it can fix those brilliant dyes, which want nothing of perfect beauty but a longer continuance of their splendour; or how far it may lead to new methods of fluxing and compounding metals, which the Indians, as well as the Chinese, are thought to have practised in higher perfection than ourselves.105

While adding a note of caution by arguing that "we must not expect from the chymists of Asia those beautiful examples of analysis which have but lately been displayed in the laboratories of Europe," Jones argued that,

The manufactures of sugar and indigo have been well known in these provinces for more than two thousand years; and we cannot entertain a doubt that their Sanscrit books on dying and metallurgy, contain very curious facts, which might, indeed, be discovered by accident, in a long course of years, but which we may soon bring to light, by the help of Indian literature, for the benefit of manufacturers and artists, and consequently of our nation, who are interested in their prosperity.106

Similarly,

the analysis of their internal properties belongs particularly to the sublime researches of Chymistry, on which we may hope to find useful disquistions in Sanscrit, since the old Hindus unquestionably applied themselves to that enchanting study; and even from their treatises on alchemy we may possibly collect the results of actual experiment. [B]oth in Persian and Sanscrit, there are books on metals and minerals. 107

Overall, William Jones's goals of establishing the Asiatic Society and of investigating the indigenous state of science and

technology were consistent with his original emphasis on devising the "best mode of ruling" Bengal and on examining the "particular advantages to our country and to mankind, which may result from our sedulous and united inquiries into the history, science, and arts these Asiatick regions, especially of the British dominions in India."108To achieve these ends, accurate and rational knowledge had to be separated from "mythology" and a "cloud of fables." The Asiatic Society of Bengal was to serve as an institutional locus for such researches. According to William Jones,

> Geography, astronomy, and chronology have, in this part of Asia, shared the fate of authentic history; and, like that, have been so masked and bedecked in the fantastic robes of mythology and metaphor, that the real system of Indian philosophers and mathematicians can scarcely be distinguished: and accurate knowledge of Sanscrit and a confidential intercourse with learned Brahmens, are the only means of separating truths from fable.109

The Asiatic Society proved to be an extremely successful organization for stimulating new scientific research. More significantly, it provided an institutional setting, while its journal, *Asiatic Researches*, and its successor, *Journal of the Asiatic Society*, provided a forum for the communication of results of scientific observations and explorations in the field. The society was also immensely successful in spawning a network of scientific organizations and institutions that eventually became independent. These included the Royal Botanical Gardens, the Indian Museum, The Zoological Gardens, the Survey of India, His Majesty's Mint, the Meteorological Department of the Government of India, the Linguistic Survey, the Medical College of Bengal, the School of Tropical Medicine, the Geological Survey, and the Anthropological Survey of India.110The society continued to be dominated by generalists in an age when science was becoming increasingly specialized, and, by the early decades of the twentieth century, William Jones's brainchild had become "an anachronism, a coterie of British gentlemen in the age of nationalist science a group of amateurs in the age of the professionals."111The trajectory of the Asiatic Society was best captured by the Indian scientist Meghnad Saha in his presidential address to the society. Saha observed, "It appears to me that the career of the Royal Asiatic Society of Bengal has been

somewhat like its great contemporary, the Great Banyan tree of the Sibpur Botanical Gardens. Like the king of trees, it has thrown all around itself ariel roots which have developed into self-contained institutions having little contact with the mother body." 112Although by the late nineteenth century it had become irrelevant as far as scientific research was concerned, Jones's Asiatic Society was instrumental in the introduction of Western science in the early phases of colonial rule, and its priorities and agenda were influenced and highly susceptible to imperial perceptions and goals. More importantly, the society provided an institutional setting for the training of scholars who immersed themselves in classical Indian literature, the "Orientalists" who participated in the now famous Orientalist-Anglicist debate of 1835. This debate had some bearing on the future trajectory and pattern of education, and consequently, science and technology in India, and will be discussed in the next chapter.

The Royal Society, Imperial Perceptions, and Botanical Gardens in Colonial India

Although colonial perceptions and goals influenced the introduction and development of a diverse range of scientific institutions, the relationship between science and empire in India is especially evident in the setting up of a network of botanical gardens in the late eighteenth century. This section examines the constellation of imperial perceptions, goals, and imperatives that led to the establishment of the Royal Botanic Garden in Calcutta. The Royal Botanic Garden, like the Royal Asiatic Society, provided the nucleus for a number of scientific societies and organizations that included among others the Royal Horticultural Society of India, the Agricultural Department of the Government of India, and the Forest Department. In addition, it played a crucial role in the the international transfer of plants of economic, commercial, and medicinal value across continents in the late eighteenth and nineteenth centuries. The botanical gardens constituted field laboratories that eventually contributed to the transformation of the amateur botanical explorer into the professional botanist and led to the production of new botanical knowledge.

Scientific Solutions for Colonial Problems: The Bengal Famines, Robert Kyd, and the Royal Botanic Garden of Calcutta

The devastating famines of Bengal in the second half of the eighteenth century provided the context for establishing a botanical garden in Calcutta. The idea

originated with Lieutenant-Colonel Robert Kyd, an officer in the Company's army and an avid amateur botanist, who realized the economic and ideological significance of centralizing hitherto haphazard botanical explorations and research in eighteenth-century India.

In the aftermath of the colonial conquest of Bengal in 1757, the province was affected by a series of devastating famines. Although precipitated by prolonged drought, the severity of the famine of 1770 was exacerbated considerably by specific colonial policies. These included continued extraction of revenues at extremely high rates of assessment despite crop failures; total neglect of preexisting irrigation systems; monopolies in grain trade dominated by the officials of the EIC and Indian traders, which led to hoarding; and diversion of rice by the colonial administration to feed its armies in Bengal and other regions. 113

The famine had a devastating impact on the population of Bengal. District records and reports indicate that provincial officials repeatedly appraised the government of the desperate situation and urged revenue reductions and remissions. On November 23, 1769, a few months before the famine set in, one British district collector wrote to the government, "It is with great concern, Gentlemen, that we are to inform you that we have a most melancholy prospect before our eyes of universal distress for want of grain insomuch that the oldest inhabitants never remembered to have known anything like it, and as to threaten a famine." However, he went to add that, "As there is the greatest probability that this distress will encrease [sic], and a certainty that it cannot be alleviated for six months to come, we have ordered a stock of grain sufficient to serve our army for that period, to be laid up in proper storehouses."114On January 4, 1770, Maharajah Shitab Roy wrote to the government that "such is the scarcity of grain in this province, that fifty poor wretches in a day perish with famine in the streets of Patna," and he urged that "expedition be used in forwarding supplies for the troops, that they may not consume the produce of the province, which is not enough for the inhabitants."115Becher, the Resident of Murshidabad, repeatedly sent dispatches to the government:

> The scene of misery that intervened, and still continues, shocks humanity too much to bear description. Certain it is, that in several parts the living have fed on the dead (June 9, 1770). Previous representations are faint in comparison to the miseries now endured. [I]n the city of Moorshedabad alone it is calculated that more than five hundred are starved daily, and in the villages and country adjacent the numbers said to perish exceed belief. [T]hose that I see dying around me, greatly affect my feelings and humanity as a man, and make me, *as a servant of the Company, apprehensive of the consequences that may ensue to the revenues*. (July 19, 1770).116

However, despite many similar representations, the revenue collection proceeded as it would have under normal circumstances. As Mr. Harwood, the officer in charge of Rajmahal district, reported on March 28, 1770, "From the motives of false policy and self-interest, the collectors in the different parts, during this calamitous season, have pressed very hard on the *ryots* to oblige them to make good their engagements to Government, that their total ruin invariably followed." 117

Even a year after the famine, when its full impact was more than evident, the government insisted on increasing the revenue collection targets to make up for the lost revenue for 1770. According to William Hunter, "In a year when thirty-five percent of the whole population and fifty percent of the cultivators perished, not five percent of the land tax was remitted and ten percent was added to it for the ensuing year."118In so doing, the colonial administration ignored the warnings of a number of its own officers, like Higginson, the supervisor of Birbhum district, who wrote to the Board of Revenue,

> I have now to represent to you, gentlemen, the bad consequences that will attend my enforcing the collections of last year's balances from the remaining poor *ryotts* of these districts who have so considerably suffered from the late famine, that by far the greatest part of them are rendered utterly incapable of paying them. By obliging them to sell their cattle and utensils for agriculture, a small proportion might be recovered; but this would certainly be the means of their deserting the province, and preventing the cultivation for the next year, which would be much more fatal to the revenue of the country than the whole of the balances. In Bissenpore, the sum of Rs. 1067 was collected on this account before I received charge of the province, and those *ryuts* from whom it was received have fled the country.119

District records and Board of Revenue accounts indicate that revenue collection targets were met during the famine of 1770. According to Governor-General Warren Hastings "the nett collections of the year 1771 exceeded even those of 1768."120

The administration responded to the crisis only when it realized that more than one-third of the total population and more than half of the cultivators, or "sources of revenue," had perished in the short span of a year. Moreover, an increasing number of the surviving cultivators, who were unable to meet demands of enhanced revenues, were deserting their lands to seek employment as agricultural laborers,121which further jeopardized the revenue interests of the EIC. The colonial administration responded by imposing a special *najay* tax in order to maintain the prefamine levels of revenue collection. Warren Hastings, who took over as governor-general immediately after the famine of 1770, defined the *najay* tax as "an Assessment upon the actual inhabitants of every Inferior description of the Lands, to make up for the Loss sustained in the Rents of their neighbours who are either dead or have fled the Country."122

Hastings admitted that "the diminution of the Revenue shou'd have kept an equal pace with the other Consequences of so great a Calamity. That it did not, was owing to its being violently kept up to its former Standard." 123But in a disingenuous attempt to "invent tradition," he claimed that the special *najay* revenue tax "was authorized by the ancient and general usage of the Country," even while arguing that,

> the same Practice which at another Time and under different Circumstances would have been beneficial, became at this period an insupportable (sic) Burthen upon the Inhabitants. The Tax not being levied by any Fixed Rate or Standard, fell heavier upon the wretched Survivors of those Villages which had suffered the greatest Depopulation, and were of course the most entitled to the Lenity of Government.124

And even after admitting the severity of the revenue collection policies of his predecessors and its devastating impact on the population of Bengal, Hastings justified the special tax by contending that "it afforded a preparation to the State for occasional Deficiencies; it was a kind of Security against Desertion, by making the Inhabitants thus mutually responsible for each other; and precluded the inferior Collector from availing himself of the Pretext of waste or Deserted Lands to withold any part of his Collections."125The only tax that was abolished immediately was the special "marriage tax," which, in Governor-General Hastings' words, "yielded a trifling Revenue to the Government," but was "very injurious to the state since it could tend only to the discouragement and decrease of the population, an object of all times of general importance, but more especially at this period."126

The devastation wrought by colonial policies on what had been one of the most prosperous regions of India continued for years to come. Resident cultivators of land, squeezed by increasing revenue assessments, kept deserting their lands, and as William Hunter has documented the situation,

> For the first fifteen years after the famine depopulation steadily increased. They had formerly been the wealthiest orders of the tillers of the soil, but now they began to look on themselves as an injured class, and so general became the desertion that in 1784, Parliament, acquainted with the signs of outward decay, but ignorant of its causes, ordered an inquiry into the reasons that had compelled the agricultural classes to "abandon and relinquish their lands". A province cannot be re-peopled, however, by Act of Parliament. The land remained untilled, and in 1789, Lord Cornwallis, after three years' vigilant inquiry, pronounced one-third of the Company's territories in Bengal to be "a jungle inhabited only by wild beasts."127

The devastating consequences of the earlier policies of revenue collection were compounded by the Permanent Settlement instituted by Lord Cornwallis on March 22, 1793.128The Permanent Settlement transformed agrarian relations by conferring private rights of land ownership to *zamindars*, who, under

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the Mughal state, functioned as tax collectors. Subsequently, peasant proprietary rights were eroded and many peasants were transformed into tenants of various descriptions. In following such a policy, Cornwallis was attempting to address

the financial and fiscal crisis of the Company by attempting to create a hereditary landed aristocracy, a practice he hoped would allow the revival of agriculture and "repair the scars left by the mortality of 1770." 129In doing so, the Company fused together two distinct conceptions of property in Mughal India: the rights to collect and profit from the collection of state revenue on the one hand, and the rights of proprietary dominion that the *zamindars* held on the other. The Permanent Settlement fixed the revenue of agricultural land at one-half the cultivator's gross yearly produce or nine-tenths the landowner's rent. This was in sharp contrast to flexible indigenous practices of revenue assessment based on actual productivity. Most importantly, failure to meet revenue payments subjected landed properties to sale through public auctions.130As the result of revenue overassessment embedded in the Permanent Settlement, many properties were put up for sale, leading to the creation of a class of absentee landlords, some of whom were rich merchants from Calcutta. Eventually, Cornwallis dispensed with "native agency" in several areas and replaced it with European collectors of revenue in order to hasten the demise of what he saw as "Asiatic tyranny."131In the long run, the Permanent Settlement, based on Whig notions of the sanctity of property and the French physiocratic doctrine that land was the basis of all wealth, did not lead to the desired results. Neither did agricultural productivity increase, since landowners relied exclusively on the appropriation of constantly increasing rents for profits, nor was the Company able to maximize revenues from agriculture. Thus, Cornwallis' objective of restoring "the Company's finances ruined by corruption and misgovernment," and achieving the "ultimate aim of realizing a regular surplus of revenue sufficient to purchase the Company's annual investment of Indian piece goods and Chinese tea," did not quite materialize.

The ruin of agriculture was further facilitated by the total neglect of existing canals and irrigation networks, a fact noted in the writings of a number of colonial administrators and one that attracted Frederick Engels' sardonic observation, "It was reserved for the enlightened English to lose sight of this in India; they let the irrigation canals and sluices fall into decay, and now at last are discovering through the regularly recurring famines, that they have neglected the one activity which might have made their rule in India at least as legitimate as that of their predecessors."132The attitude of the Company during the early phase of colonial rule was summed up by Colonel Chesney, an official in India, who wrote that

> the Court of Directors, until almost the termination of their existence, did not recognize the prosecution of public works as a necessary part of their policy. The construction of a road or canal was regarded by them, in their

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> earlier days, much in the same light that a war would beas an unavoidable evil, to be undertaken only when it could not be postponed any longer, and not, if possible, to be repeated. 133

Organized and extensive repair of ruined irrigation systems and canals was eventually undertaken by the colonial administration after the constitution of the Public Works Department in 1854.134

Although most British administrators were aware of the social and economic consequences of the harsh revenue policies, the application of science and technology to alleviate colonial problems promised solutions that could ensure high revenues and help in the consolidation of the economic position of the Company, without any restructuring of existing social relations. In the context of the devastating famines of Bengal, it is easy to understand why the Board of Directors responded enthusiastically to a proposal for the establishment of botanical gardens.

On April 15, 1786, Lieutenant-Colonel Robert Kyd wrote a detailed letter to the Board of Revenue in Calcutta. Kyd's initial letter is worth quoting at some length, as such candor by an official of the Company was rare:

> Revolving in my mind the accumulated riches which have accrued to Great Britain, consequent to the acquisition of our Territorial possession in India, I have been sometimes betrayed into reflections on the comparative benefits which we have conferred on the Nations of India, whom the right of conquest has subjected to our Government. In this comparison, I am afraid, *the balance will stand greatly against us*; for setting aside the protection which our arms have afforded these provinces from the desolation of war, *a benefit in which we were equally interested*, and the introduction of our constitutional laws for the protection of their persons and properties (!) *I know not of any other benefit we can claim of the merit of affording them*.135

After discussing the horrors of the Bengal famines, which were ascribed to purely "physical causes incident to the Climate of Hindostan," and which had "devastated these fair provinces from one extremity to the other," Kyd expressed grave concern over the possibility of the Indians "entailing on us the imputation of inhumanity, and improvidence from

the enormity of misery and wretchedness, which inevitably continues to impend over the heads of the Natives whilst every provisional plan remains unattempted on the part of our Administration."136

Kyd's proposed solution was the introduction of the Malayan sago palm to Indiaa plant "affording a species of food, highly valued, and eagerly sought after by the natives of every denomination of our Government."137He urged the EIC to procure sago palms in large numbers from Malaya and to transplant them in Calcutta from where they could be distributed to other parts of British India. Kyd argued that "the dreadful calamity in question [the famines] may (if not wholly) in part be averted by the means proposed, which

will afford an everlasting resource, and be no further chargeable to Government than its first introduction." 138On June 1, 1786, Kyd followed up his first letter with another one, this time proposing the transfer of the cinnamon trees from Assam to Calcutta in order to offset the commercial advantage the Dutch had from their possession of cinnamon plantations in Ceylon. In his second letter, Kyd enclosed drawings of a number of spices and herbs such as pepper, cardamom, nutmeg, cloves, camphor, etc. that had high market value, and could be transplanted in his proposed experimental botanical gardens in Calcutta. He noted that he had been

> induced to throw out those communications in hopes of its being the means of awakening the nation at large to a sense of the inestimable Treasures, which we already hold in our extensive Dominions, in this part of Asia, and if possible divest Administration not only from thinking of making further acquisitions by new Settlements but in as much as they may prove absolutely necessary for the preservation and security of what we already hold but also to embrace the opportunity of peace to reject such unprofitable parts of our possession to enable us to outstrip our Rivals in every valuable production which nature has confined to this part of the Globe, but has showered down with so bountiful and partial a hand over our possessions and which if attended to, cannot fail to prove a further resources of riches to, Great Britain.139

Robert Kyd concluded his proposal by pointing out

> the propriety of establishing a Botanical Garden not for the purpose of collecting rare plants (although they also have their use) as things of mere curiosity or furnishing articles for the gratification of luxury, but for establishing a stock for the disseminating such articles as may prove beneficial to the Inhabitants, as well as the natives of Great Britain and ultimately may tend to the extension of the national Commerce and Riches.140

Robert Kyd's proposals were received by the Board of Directors at a time when the Company was in financial trouble and was finding it hard to justify the export of bullion to India. The debt of the Company, combined with rapidly declining revenue from agriculture due to the Bengal famine, led the Board of Directors to search for new commodities, especially botanical products like spices, dyes, and drugs. The Company had employed a number of botanists in India in the past. One such employee, Johan Koenig, who had been confident of his ability "to repay his Employers a thousand Fold in matters of investment, by the discovery of Drugs and Dying materials fit for the European market but above all by putting the Company in possession of articles proper for the Chinese investment such as that nation at present receives from other people," had died in June 1785.141Although Governor-General Warren Hastings and Company chairman Charles Grant had experimented with private botanical gardens in Bengal, the Company was now interested in

turning to botanists for expert advice on the diversification of trade and commerce.

Henry Dundas, the president of the newly constituted Board of Control overseeing the financial affairs of the Company, referred Kyd's proposal to Sir Joseph Banks, the president of the Royal Society. Banks had considerable experience in the establishment of botanical gardens in St. Vincent in the West Indies for the introduction of breadfruit from Tahiti as "food for slaves." 142He responded enthusiastically to Kyd's proposal and offered his opinion to the Board of Control:

> [I]f we consider for a moment that the merchandise hitherto brought home from India have been chiefly manufactures of a nature which interferes with our manufactures at home, that our cotton manufacturies above,

> all, are increasing with a rapidity which renders it politic to give them effectual encouragement, and that a profit of Cent per Cent upon the importation of the raw material of cotton is to be got with certainty, can we too much encourage everything which tends to the cultivation of raw materials in India? Labourers are abundant there: Labour excessive cheap: raw materials of many sorts, dying drugs, Medecines (sic), Spices &c sure of a ready and advantageous market and of producing a most beneficial influence upon the Commerce of the mother Country.143

Assured by Joseph Banks's positive evaluation of Kyd's proposal, the Board of Control and the Court of Directors dispatched a letter to the governor-general at Calcutta. In the letter, dated July 31, 1787, the Court of Directors conveyed their

> great pleasure from the perusal of Lieutenant-Colonel Kyd's letter proposing the establishment of a Botanical Garden, and give our most hearty approbation to the institution. The experiment respecting the cinnamon tree in particular must be made in different parts and soils of those extensive Provinces, in order to ascertain with certainty whether this spice can be produced in Bengal equal to that which grows on the island of Ceylon. You must keep us constantly advised of the progress that may be made in the botanical Garden, and continue to send us drawings of such of its productions as you deem worth of attention. *[S]o sensible are we of the vast importance of the objects in view, that it is by no means our intention to restrict you in point of expense in the pursuit of it*. In the cultivation of the cinnamon tree in particular, we foresee a great source of wealth to the Company, and of population and opulence to the provinces under your administration.144

Although the dispatch from the Court of Directors of the Company made a passing reference to Kyd's original objective of using botanical gardens as nurseries for transplanting sago palms to avert famines in the future, the main focus of attention was the potential for rescuing a Company that was in financial trouble.

The proposal to introduce sago palms was never implemented, and Kyd's long list of plants that could be raised in the nursery was geared to benefit the Company and Britain. 145Such an approach was consistent with Sir Joseph Banks's advice that it was desirable to introduce crops into India that were "not likely to produce rivalship with the Mother Country."146

Within four years of Robert Kyd's proposal, grants from the Company led to the establishment of botanical gardens at Calcutta, Madras, Bombay, and St. Helena. The EIC also provided salaries for the positions of superintendent of the gardens. Robert Kyd, the first superintendent of the Calcutta botanical garden, introduced a number of commercially useful plants, including cinnamon, coffee, black pepper, and nopal, the host plant for the cochineal insect.147The move for the establishment of the Madras botanical garden was initiated by James Anderson, a Company surgeon and amateur botanist, whose botanical mission was to weaken the Spaniards' monopoly in the production of expensive cochineal dye. To accomplish his objective, Anderson was attempting to propagate a species of the host plant for the cochineal insect from which the dye was obtained. Initially, Anderson had experimented with a number of local grasses, but his attempt to raise the cochineal insects on them were unsuccessful. His attempt to introduce the nopal plant, or *Opuntia cochinillifer* into India led to the establishment of a nursery at Madras that was initially known as the "Honourable Company's Nopalry."148The nopal plant was introduced from the Kew Gardens, Canton, and Mexico, and a year later, over eight hundred species of exotic as well as indigenous plants were thriving in the "Honourable Company's Nopalry."149The Bombay botanical gardens were established in 1791 through the initiative of Dr. Helenus Scott, a regular correspondent of Joseph Banks, with the aim of conducting experiments in the cultivation of sugar, indigo, tobacco, coffee, etc. Finally, the garden at St. Helena was established due to its strategic location at the center of a number of maritime routes. Because of its location within the tropics, it was used as an extended "transit lounge," useful for the acclimatization of plants being transferred across hemispheres. By the early part of the nineteenth century, a number of botanical gardens had been established in various parts of British India.

Botanists, Botanical Gardens, and Imperial Trade: Tea and Cinchona

Throughout the nineteenth century, the Company's botanists and botanical gardens played a major role in the transfer of commercial plants and crops across continents that contributed to the consolidation expansion of British colonial power. Tea and cinchona, two plants that significantly affected the fortunes of the British empire could not have been transferred

across national

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and continental boundaries without the expertise of the Company botanists and institutional support from the newly established botanical gardens in India.

The initial impetus for the transfer of the tea plant from China to British India came in the context of growing financial problems for the Company and concern over the export of bullion to pay for it. 150In the latter half of the eighteenth century, Britain was importing large quantities of tea from China that was paid for in bullion. For example, in 1786, approximately eight hundred thousand pounds sterling was paid by the Company for the purchase of tea from Canton. Robert Kyd, in his original proposal, had indicated that, since similar climatic conditions prevailed in China and in Indian regions under the control of EIC, tea could be cultivated on an experimental basis at the Calcutta botanic garden. Joseph Banks, the president of the Royal Society, had been enthusiastic about the idea, pointing to the "numerous race of frugal and intelligent natives" used to working for low wages and the "few, if any, instances being known of Plants brought from one intertropical climate refusing to thrive in another."151

The superintendent of the Company's botanical garden at Saharanpur had reported that India's Himalayan foothills would be ideal for the cultivation of tea. The area between Bengal and Bhutan was selected as most suitable for the first experiments in tea transfer. Joseph Banks suggested that the acquisition of the expertise and skill required for tea cultivation and manufacture would be facilitated by the transfer of some Chinese cultivators, who could be placed under the "able and indefatigable superintendent" of the Calcutta botanic gardens, along with the plants.152There were, however, difficulties in procuring suitable plants and Chinese cultivators from Canton. Consequently, only small consignments received between 1789 and 1790 grew well in the Calcutta botanical gardens. The situation changed dramatically after the Opium Wars. In 1848, the Company commissioned Robert Fortune, a botanist with experience in China, to procure suitable tea varieties from China. Fortune returned to India in 1851 with over two thousand tea plants and seventeen thousand tea seeds, together with indigenous expertise in the form of a number of Chinese tea farmers.153

At the same time, the Company's botanists working at the gardens in Calcutta and Saharanpur had undertaken expeditions to the north-astern regions of India and had discovered the existence and cultivation of indigenous varieties of tea. William Griffith, one of the superintendents of the Calcutta gardens (18421844), had traveled to Assam to search for tea, teak, and mines.154In 1847 he had reported that "the article [tea] is procurable here," and had observed and described the cultivation of a number of varieties, including "bitter tea."155The Company acquired lands around Darjeeling in northeastern India, and, with the help of its botanists and Chinese and Indian cultivators and laborers, began cultivating indigenous varieties of tea on large

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plantations. By the latter half of the nineteenth century, tea became one of British India's principal exports. Indian tea supplanted Chinese tea in the international market. The term "Darjeeling," the name of the place where one of the first plantations began, continues to be synonymous with fine Indian tea.

The Company's Troops, Malaria, and the Transfer of Cinchona Plants from South America

In addition to facilitating the intercontinental transfer and propagation of plants of economic value, the botanical gardens and botanists proved to be invaluable when the Company's armies were threatened by malaria in India. The rebellion of 1857, which lasted over eighteen months, came as a major surprise and psychological shock for the British in India. Amongst other changes, the rebellion of 1857 led to the abolition of the EIC, which was replaced by direct Crown control, administered through a secretary of state and a council for India. These administrative changes were accompanied by a number of social changes in India. 156

One such change was the increase in the racial divide between the British and the Indians. Prior to this period, marriages and sexual alliances between Indian women and English men were not uncommon, as the latter were officially discouraged from bringing their families to India. After the rebellion, such alliances were discouraged and the expansion

of the bureaucracy led to English administrators bringing their families along with them to India. More significantly, the rebellion of 1857 led to a major reorganization of the armed forces. From the British point of view, Indian soldiers could no longer be trusted, and the number of British soldiers in the armies was increased dramatically. Furthermore, due to the perceived dubious loyalty of Indian sepoys, artillery was restricted to British troops only.157The dramatic increase in British population led to renewed concern over the ever-present threat from a disease like malaria. Although malaria is not a "tropical disease"the term malaria comes from the Italian for "bad air"it had disappeared from England and France by the seventeenth century. The vulnerability of the British army to malaria was of particular concern as large numbers of soldiers were succumbing to the disease.

It was in the context of such demographic changes and heightened concern about the vulnerability of the army that the project of transplanting cinchona trees from the Peruvian Andes to India was planned and executed. By the early seventeenth century, it was well known that the Peruvian Indian healers were using the bark of the cinchona tree to cure fevers, and *Anastasis Corticis Peruviae*, a Latin treatise of 1633 published in Geneva had described the treatment process in detail.158In addition, the naturalist Alexander von

Humboldt had explored the Andes between 1799 and 1804. Although the idea of transferring cinchona to India had been proposed by Joseph Banks in the early nineteenth century, the attempt had not been successful. 159The government was already spending a substantial amount of money for importing quinine into India, but by the mid-nineteenth century, the medical and administrative authorities feared that the supply of quinine-yielding cinchona from South America might be disrupted. In 1855, the medical board in India had dispatched an urgent letter to the "President in Council" at Fort William expressing their concern over the "danger of a failure of the cinchona supply in America, under the annually increasing demands for the medicinal bark from nearly all parts of the world."160Urging the government to arrange for an expedition designed to transfer cinchona plants from South America to India, the members of the Medical Board argued that "officers possessing the requisite botanical and geological knowledge should be deputed to inquire into those sites which appear to be best calculated to receive the plants. That these officers being liberally furnished with the necessary aid and appliances, should receive the plants upon their arrival in India, and convey them forthwith to the spots prepared for their reception."161The members of the medical board impressed upon the government the gravity of the situation by contending,

> At the present stage of this inquiry, it is almost needless that we should insist upon the advantages which would result from the success of such an experiment. The fact that in the five years 184953 nearly 54,000 1. [sterling pounds] were expended by the Honourable East India Company upon quinine and chinchona bark in the three Presidencies of India is, we would urge, of far less imperative import than the well-established certainty that the failure, and possibly the extinction of the South America cinchona supply is actually threatened, and that India is the only other country in the world which appears to afford a fitting habitat for the cinchonaceae.162

The earlier transfer of tea from China to India provided the model that was followed in this case. On April 5, 1859, Clements Markham, then a junior clerk at the India Office, volunteered to lead an expedition to Peru and Bolivia for the collection of seeds and seedlings. Markham claimed that he was best qualified for the task because,

> I am well acquainted with several of the forests in Peru, and on the frontiers of Bolivia, containing the cinchona tree. I already know three of the more useful species by sight, and should be able to acquire a thorough knowledge of the others before leaving England. I know not only the Spanish language, but also the Quichua, or language spoken by the Indians of those districts; and I am intimate with many of the public men and the landowners on the eastern slopes of the Cordillera. I trust I may add that I am most anxious to perform this service well, which I feel to be of such great importance. Considerable tact also is required in order to avoid exciting jealousy in the

> minds of Government officials. These facts are pointed out, in order to show how fruitless it will be to trust to agents and consuls, and how necessary it is to employ some person whose heart is really in the business. 163

On April 8, 1859, less than three days after Markham's proposal, the Revenue, Judicial, and Legislative Committee passed a consenting resolution that was approved by the secretary of state for India. In part the resolution read:

> It appears to the Committee that having regard to the urgent importance in both a medical and an economical point of view, of introducing the plant into India without further loss of time, and to take the failure of the attempts hitherto made to procure the services of a suitable collector, it is advisable to take advantage of the offer of Mr. Markham, and to entrust to him the proposed commission.164

In the months that followed, there was a flurry of communication between the secretary of state for India and the colonial authorities as well as the superintendent of the Calcutta botanical garden. Lord Stanley wrote immediately to the governor-general of India, asking him to "call upon the Superintendent of the Botanical Gardens at Calcutta," to obtain "his opinion respecting the best locality for planting the cinchona in your Presidency, and with any other observation which he may deem useful, respecting the cultivation of those plants in India."165The governor-general immediately passed a minute that "officers possessing the requisite botanical and geological knowledge should be deputed to inquire as to the sites best calculated to receive the plants; that these officers, duly supplied with all aids and appliances, should receive the plants upon arrival, and convey them to the selected spots."166The English botanists in cooperation with meteorologists, began surveying various regions in India in search of "a very humid, temperate climate, in which there is but little variation of temperature throughout the year, so that the tree is never subject either to a powerful sun or to severe frost."167

Meanwhile in England, Markham's plan was evaluated and approved by William J. Hooker, the director of the Kew Gardens. Hooker also recruited Richard Spruce, a Kew botanist who was already in Ecuador collecting botanical specimens, and dispatched another botanist, Robert Cross, to collaborate on the project.168On December 31, 1860, after knowingly violating stringent Peruvian and Bolivian laws against the export of cinchona, which was a government monopoly, Markham and his colleagues were eventually successful in shipping out nearly one hundred thousand dried seeds and 637 young plants for India via England.169The plants were reared in the Calcutta botanical garden for a while, before being transplanted on plantations in the regions of the Nilgiri Hills by convict laborers. Later, new plantations were established in a number of other areas like Sikkim and Ceylon. The whole process of the transfer of cinchona from South America to India was a colossal undertaking in which the botanists, botanical expertise, and the network of botanical gardens both in

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India and England played crucial roles. A number of botanical and chemical experiments were carried out before the plantations and the production of quinine was successful. The years 18601879 witnessed a number of botanical experimentation in hybridization. The botanist William G. McIvor, who was the superintendant for cinchona cultivation, engaged in a number of experiments and developed a method of increasing the amount of bark to be harvested for the manufacture of quinine. 170

Most British officials emphasized the humanitarian aspects of the development of cinchona plantations and manufacture of quinine in India. Thus Clements Markham, who undertook the original expedition to Peru, could claim that "few greater blessings have been conferred on the human race than the naturalisation of these trees in India and other conquered regions. [It] will be one of the measures for which British rule in India will be entitled to the gratitude fo the people of India."171In a similar vein, the eminent botanist, Joseph Hooker claimed that "a dose of five grains of quinine in a paper bearing a Government stamp may be bought at any post office in Bengal for half a farthing."172However, as Lucile Brockway has pointed out, "this is how they remembered the cinchona transfer, and how they wanted it to be remembered."173Not everyone in India could purchase the cure for malaria at any post office. Even in Bengal, the only province where it was available to the public, the greater part of the the quinine production went to the Government Medical Stores for the use of troops, British officials, and their families. As Brockway has argued,

> the bulk of Indian production for the home market was directed toward the British establishment, both military and civilian, enabling the British officer and his Indian soldiers to resist malaria and stay in fighting trim, enabling the British civil servant and his Indian assistants to perform their duties in good health, without the ravages of periodic bouts of fever, and enabling the British sahib to bring his wife and children to live in India.174

The above discussion makes clear that botanists, botanical knowledge, and the network of botanical gardens stretching

across continents played a major role in the expansion and stabilization of the British empire. The cinchona cultivation and the production of quinine were also indispensable for the British conquest of Africa. Without a good supply of quinine, the British troops would not have survived the malaria-prone regions of Africa.175The connection between the botanical gardens of Calcutta, the application of botanical knowledge for the transfer of cinchona from South America to India and the expansion and exercise of colonial power was best expressed by Surgeon Major G. Bidie of the British Army of Madras presidency: "To England, with her numerous and extensive Colonial possessions, it is simply priceless; and it is not too much to say, that if portions of her tropical empire are upheld by the bayonet, the arm that wields the weapon would be nerveless but for Cinchona bark and its active principles."176

The Production of Botanical Knowledge and the Reproduction of Colonial Rule

Although the exploratory researches of botanists and botanical gardens that eventually evolved into experimental research stations contributed to the reproduction of colonial relations and structures in India, the colonial encounter also led to the production of new botanical knowledge and to the emergence of botany as a modern scientific discipline. As in the case of the geographers and surveyors discussed earlier, the botanists of the EIC and the colonial government were engaged in delicate balancing acts between their interest in botany and their attempts to seek patronage for their researches by articulating their scientific knowledge within the context of the imperatives of colonialism. As demonstrated above, successive colonial administrators in India were quick to realize the economic and political significance of scientific knowledge and institutions in the reproduction of colonial rule, even though, in the initial phase, the Court of Directors of the Company could not grasp the importance of scientific research for a trading company.

This "complex social embeddedness and autonomy of scientific thinking" is clearly evident in the botanical researches of a number of early explorers. Thus, Hendrik Adrian van Rheede, a Dutch surgeon who began his career with the Dutch East India Company in 1656, offered his services as a botanist to explore the Malabar coast and Ceylon to search for medicinal plants and herbs. 177As in the case of cinchona, the Dutch East India Company was concerned about the escalating cost of medicines from Europe. The supplies of medicines were essential for the troops of the Company, and to offset the costly importation of medicines from the Netherlands, van Rheede offered to explore the Malabar coast of India for medicinal plants. Seven years of intensive exploration, with the assistance of a number of Indian physicians who were indispensable because of their familiarity with the plants and the languages, led to the publication of the twelve-volume *Hortus Malabaricus* (1678). Van Rheede's *Hortus Malabaricus* was the "first comprehensive printed book on the natural plant resources of the Indian subcontinent written in a European language,"178and its publication in the Netherlands constituted an important event in the history of botany and taxonomy.

Consisting of twelve volumes describing and classifying 690 species and containing 793 illustrations in double-folio size, the *Hortus Malabaricus*, written in Latin, provided the name and classification of each species in no less than five languages, including three Indian languages.179Van Rheede's botanical magnum opus was reviewed immediately in the leading scientific journals of Europe*Journal des Scavans*, *Philosophical Transactions*, *Acta Eruditorum*and in the following years, a number of commentaries on it appeared. The *Hortus Malabaricus*' description and classification of several

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new species was incorporated in the work of the leading taxonomists and scientists of Europe like Linnaeus, Lamarck, Burman, and Adanson, who established many generic names based on names provided by van Rheede. More significantly, van Rheede's work was incorporated by the "father of taxonomy," Carl Linnaeus, in his *Flora Zeylanca* (1747), *Systema Naturae* (1759), and *Species Plantarum* (1753). The publication of the latter work signalled the beginning of the modern Linnaean binomial system of nomenclature. Van Rheede's *Hortus Malabaricus* not only played an important role in the history of plant taxonomy but continues to attract the attention of modern botanists. 180As a historian of botany has observed, "the great attention which botanists of the early part of the [19th] century had given to taxonomic questions and the problems of geographical botany was largely the outcome of the growth and expansion of the Colonial and Indian Empire during those years."181

Van Rheede's *Hortus Malabaricus* was also significant as it was the inevitable starting point of reference work for the first botanists associated with the EIC. Francis Buchanan, whose extensive topographical and botanical surveys of Bengal and Mysore have been discussed above, was also the first to publish an extensive commentary on van Rheede's work in the *Transactions of the Linnean Society* (18221835). Van Rheede's work enabled Buchanan as well as other botanists employed by the EIC to get their botanical bearings in the new region of India. One such botanist was William Roxburgh, who relied on Rheede's work to conduct botanical researches and surveys that led to the publication of *Plants of the Coast of Coromandel* (1795), *Hortus Bengalensis* (1814), the multivolume *Flora Indica* (1820), and *Icones Roxburghianae; or Drawings of Indian Plants*. In turn, William Jones utilized the work of William Roxburgh and other botanists of the EIC to carry on his own botanical researches. Jones published at least four papers on botanical classification, and his contribution to botany was acknowledged by William Roxburgh who named an Indian plant, *Jonesia asoca*, after him.

Finally, Joseph Dalton Hooker, the director of Kew Gardens and a graduate of Glasgow University, had spent four years (18471851) surveying the border area between Bengal and Sikkim in the mid-nineteenth century. The project enabled him to collect and transfer seven thousand specimens of Himalayan plants to Kew and led to the publication of his *Flora of British India* (18721897), which relied on van Rheede's work.182J. D. Hooker's botanical surveys of India and other regions of the world contributed significantly to the evolutionary theory of his close friend Charles Darwin. Joseph Hooker's wide-ranging botanical explorations provided Darwin with material for reflection on the meaning of the distribution of species and local variation of species. Hooker was the first confidant of Charles Darwin and read his essay on the origins of species in manuscript form, even though he himself argued for the permanence of species and was not initially convinced on the question of origins.183However, by January 25, 1859, Darwin could write to

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Alfred Russel Wallace that "Dr. Hooker has become almost as heterodox as you or I, and I look at Hooker as *by far* the most capable judge in Europe." 184

Overall it should be evident that although the scientific research initiated in the early phases of colonial rule contributed to the reproduction of colonialism, it also led to the production and development of new scientific knowledge. There emerged a symbiotic relationship between the production of scientific knowledge and exercise of colonial power. The connections among science, technology, and colonialism were further strengthened in the later phases of colonial rule in India, and this relationship constitutes the main topic of discussion in the next chapter.

Notes

1. Clements Markham, 1878: 399,146.

2. Dispatch from the Court of Directors of the East India Company to Fort St. George (Madras), 1810. Reprinted in the *Journal of the Royal Asiatic Society of Great Britain and Ireland*, vol. 1, 1835: 361.

3. James Rennell, quoted in Markham, 1895: 83.

4. Alfred Chatterton, 1912: 359.

5. Arthur Wellesley, cited in C. Bayly, 1990: 90.

6. S. Visvanathan, 1985: 814.

7. H. H. Gerth and C. Wright Mills, 1964: 78.

8. S. N. Eisenstadt, 1963: 19.

9. Ainslie T. Embree, 1989: 69. See also Gregory Nobles, 1993, for an excellent analysis of the role of cartography in establishing hegemony in a different context.

10. Embree, 1989: 77.

11. *Ibid.*, 7274.

12. Bayly, 1990: 50.

13. Markham, 1878: 58.

14. Markham, 1895: 42.

15. *Ibid.*, 1895: 4344.

16. Vansittart to Rennell, cited in Markham, 1895: 45.

17. Robert Orme, cited in T. H. D. La Touche, 1910: 151. R. Orme, 1778 and 1780 are based on the charts, surveys and maps prepared by Rennell.

18. While surveying the region of Bhutan, which was not under the control of the Company, Rennell had been wounded in a confrontation with local residents.

19. Robert Clive to the Court of Directors, cited in G. F. Heaney, 1957: 182.

20. Rennell, 1792: 33564.

21. The inland navigation map is included in Rennell, 1792: 364.

22. Rennell, 1792: 33537.

23. Heaney, 1957: 182.

24. P. J. Marshall, 1987.

25. Markham, 1895: 57.

26. For Joseph Banks's role and influence in the patronage of science in eighteenth-century England, see Charles Lyte, 1980; Patrick O'Brien, 1987; Harold Carter, 1988.

27. Markham, 1895: 64.

28. Rennell, 1792, dedication to Joseph Banks.

29. Joseph Banks, cited in Markham, 1895: 9697.

30. Markham, 1895: 89; Heaney, 1957, offers 1752 as the date for D'Anville's *Carte de India*.

31. Markham, 1878: 399.

32. *Ibid.*, 58.

33. For the arguments in this section, I rely on: J. N. L. Baker, 1963, and Markham, 1895.

34. Rennell, 1792: 33537.

35. Edward B. Bailey, 1967.

36. J. Hutton, 1795: 210, cited in Baker, 1963: 143.

37. Richard Kirwan, cited in Baker, 1963: 144.

38. John Playfair, 1964: 42829.

39. H. T. de le Beche, 1833: 74, cited in Baker, 1963: 145.

40. Markham, 1895: 16063.

41. *Ibid.*, 169.

42. Baker, 1963: 147.

43. *Ibid.*, 152.

44. Chandra Mukerji, 1991: 905.

45. Steve Woolgar, 1988.

46. Rennell, cited in Baker, 1963: 138.

47. Colonel Mackenzie's letter to Alexander Johnston, dated February 1, 1817. Reprinted in *Journal of the Royal Asiatic Society of Great Britain and Ireland*, vol. 1, 1835: 337.

48. W. C. Mackenzie, 1953: 53.

49. *Society of Gentlemen*, 1763, cited in W. C. Mackenzie, 1953: 26.

50. Cited in W.C. Mackenzie, 1953: 45.

51. Cited in W.C. Mackenzie, 1953: 74.

52. Colin Mackenzie to Alexander Johnson, *Journal of the Royal Asiatic Society*, 1834: 87.

53. Marika Vicziany, 1986: 642.

54. Francis Buchanan, 1807.

55. Cited in S. B. Chaudhuri, 1964: 4245.

56. Vicziany, 1986: 62728.

57. *Ibid.*, 628.

58. *Ibid.*, 633.

59. *Ibid.*, 633.

60. *Ibid.*, 63334.

61. *Ibid.*, 63940.

62. *Ibid.*, 643.

63. *Ibid.*, 645, 656.

64. Joseph Hooker, 1904: 2, cited in Vicziany, 1986: 659.

65. In addition to the reports of the surveys of Mysore, Bengal, and Bihar, Buchanan published scientific papers and books under the family name Hamilton. See Francis Hamilton, 1822 and 1826.

66. D. J. Mabberley, 1977: 525.

67. Mabberley, 1977: 52340.

68. Vicziany, 1986: 647.

69. Extract from a general letter from the Home Public Department signed by D. Hill and dated 9 February 1810, to the Government of Fort. St. George. Reprinted in *Journal of the Royal Asiatic Society*, 1834: 361362.

70. Cited in Embree, 1989: 80.

71. Visvanathan, 1985:10; Lewis Fermor, 1935: 922.

72. Edward Ellsworth, 1991.

73. Susan Cannon, 1978: 105.

74. Bayly, 1990: 89.

75. Michel Foucault, 1991. See also Ian Hacking, 1991, for a good discussion on the rise of "statistics."

76. E. J. Hobsbawm, 1991: 10.

77. William Jones, 1799 [1784]: xxi.

78. Jones, 1799 [1784]: ix.

79. Jones, 1799 [1784]: xiv.

80. Garland Cannon, 1975: 208.

81. Jones, 1799 [1784]: xiv.

82. Jones, 1799: v.

83. Warren Hastings. Letter to the Asiatic Society, 30 January, 1784. Reprinted in *Asiatic Researches*, vol. 1, 1799: vii.

84. O. P. Kejariwal, 1988.

85. Suniti Kumar Chatterji, 1948: 8287.

86. Jawaharlal Nehru, 1946: 317.

87. Bernard S. Cohn, 1985.

88. Kejariwal, 1988: 29.

89. *Ibid.*

90. *Ibid.*, 31. See also *ibid.*, 241 for Jones's memorandum enumerating the languages he had studied: "Eight languages studied critically: English, Latin, French, Italian, Greek, Arabic, Persian and Sanskrit; Eight studied less

perfectly, but all intelligible with a dictionary: Spanish, Portugese, German, Runick, Hebrew, Bengali, Hindi, Turkish; Twelve studied least perfectly, but all attainable: Tibetan, Pali, Pehlavi, Deri, Russian, Syriac, Ethiopic, Welsh, Swedish, Dutch, Chinese."

91. Visvanathan, 1985: 8.

92. Jones, 1799 [1785]: 407.

93. Jones, 1799 [1786]: 421.

94. Jones, 1799 [1785]: 411.

95. Jones, 1799 [1786]: 430.

96. Jones, 1799 [1790]: 345.

97. Jones, 1799 [1785]:408.

98. Jones, 1799 [1790]: 34546.

99. *Ibid.*, 352.

100. *Ibid.*, 348.

101. Lucile H. Brockway, 1979: 6.

102. Jones, 1799 [1790]: 348.

103. Jones, 1799 [1793]: 14.

104. *Ibid.*

105. Jones, 1799 [1785]: 409.

106. Jones, 1799 [1793]: 16.

107. *Ibid.*, 13.

108. Jones, 1799 [1792]: 492.

109. Jones, 1799 [1793]: 9.

110. Visvanathan, 1985: 12.

111. *Ibid.*, 14.

112. M. N. Saha, 1946: xvi, cited in Visvanathan, 1985: 14.

113. A. C. Banerjee, 1980: 12931; Aditee N. Chowdhury-Zilly, 1982: 2021.

114. William Hunter, 1868: 399. Appendix B.

115. Hunter, 1868: 405.

116. *Ibid.*, 41819.

117. *Ibid.*, 418.

118. *Ibid.*, 39.

119. *Ibid.*, 413.

120. *Ibid.*, 381. Appendix A.

121. This phenonemon has been analyzed in some detail by Chowdhury-Zilly, 1982.

122. Warren Hastings, 1868: 381.

123. *Ibid.*

124. *Ibid.*, 382.

125. *Ibid.*

126. *Ibid.*, 381.

127. Hunter, 1868: 6061.

128. See Banerjee, 1980; R. Guha, 1981 [1963]; R. Dutt, 1969 [1902]; Chawdhuri-Zilly, 1982; and R. Ray, 1979, for a discussion on various aspects of the Permanent Settlement.

129. Bayly, 1990: 65.

130. *Ibid.*, 66.

131. *Ibid.*

132. Frederick Engels, 1954: 249. For an analysis of the neglect of irrigation systems under the first phase of colonial rule, see Kathleen Gough, 1978: 2553.

133. Col. George Chesney, cited in John Strachey, 1911: 233.

134. Strachey, 1911: 234; Arun Bandhyopadhyayay, 1991: 95.

135. Robert Kyd. Letter to the Board of Directors. Fort William, 15 April 1786. Reprinted in Kalipada Biswas, 1950: 3.

136. Biswas, 1950: 34.

137. *Ibid.*, 4.

138. *Ibid.*, 5.

139. *Ibid.*, 8.

140. *Ibid.*, 7.

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141. David Mackay, 1985: 172.

142. *Ibid.*, 127.

143. Joseph Banks, cited in Mackay, 1985: 175.

144. Biswas, 1950: 1011.

145. Mackay, 1985: 180.

146. Joseph Banks, cited in Mackay, 1985: 182.

147. Mackay, 1985: 177.

148. *Ibid.*, 178.

149. *Ibid.*

150. For the arguments of this section, I draw extensively on Mackay, 1985: 18182 and Brockway, 1979: 2728.

151. Mackay, 1985: 175.

152. *Ibid.*, 181.

153. Lucile H. Brockway, 1979: 27. A firsthand account of this expedition can be found in Robert Fortune, 1852.

154. William Griffith, 1971 [1847]: 70, 9192, 96.

155. *Ibid.*, 70, 92.

156. For a good account of the rebellion and its consequences, see T. R. Metcalf, 1973.

157. Brockway, 1979: 106.

158. *Ibid.*, 109.

159. *Ibid.*, 112.

160. Medical Board. Letter to the Hon. J. A. Dorin, President in Council. Fort William, 9 June 1855. Parliamentary Papers. House of Commons. 1863: 13.

161. Parliamentary Papers. House of Commons. 1863: 15.

162. *Ibid.*, 15.

163. Clements Markham. Letter to Sir George Clerk, 5 April 1859. Parliamentary Papers. House of Commons. 1863: 21.

164. Parliamentary Papers. House of Commons. 1863: 22.

165. *Ibid.*, 23.

166. A. H. Blechynden, Secretary, Agricultural and Horticultural Society. Minute to W. Grey, Secretary to the Government of India. Parliamentary Papers. House of Commons 1863: 24.

167. Thomas Thomson. Letter to the Secretary to the Government of Bengal, 6 September 1859. Parliamentary Papers. House of Commons. 1863: 24.

168. Brockway, 1979: 113.

169. *Ibid.*, 115.

170. *Ibid.*, 11819.

171. Markham, 1880: iv, 1.

172. Joseph Hooker, cited in Brockway, 1971: 124.

173. Brockway, 1979: 124.

174. *Ibid.*, 126.

175. Daniel Headrick, 1981.

176. G. Bidie, 1879, cited in Brockway, 1979: 103.

177. This section on van Rheede's botanical research relies on Dan H. Nicholson, C. R. Suresh, K. S. Manilal, 1988.

178. Nicholson et al., 1988: 18.

179. *Ibid.*, 14.

180. Nicolson et al., 1988; K. S. Manilal, C. R. Suresh and V. V. Sivarajan, 1977: 54950.

181. Joseph Reynolds Green, 1909: 536.

182. See J. D. Hooker, 1969 [1852], for an account of Hooker's botanical expedition to India.

183. Brockway, 1979: 94.

184. *Ibid.*, 95.

6
Science, Technology And Colonial Power

Native thought and literature is elaborately inaccurate; it is supremely and deliberately careless of all precision in magnitude, number and time. The Indian intellect stood in need, beyond and everything else, of stricter criteria of truth. It required a treatment to harden and brace it, and scientific teaching was exactly the tonic which its infirmities called for.
Sir Henry Maine 1

There is a warof principle, between light and darkness, truth and error. [T]he absurd systems of Hindoo geography and astronomy, and their stupid fictions in natural science, rest upon one foundation, which demonstration and experiment could easily overthrow; the extension of true science would, therefore, undermine the fortress of error and delusion. The enterprise of British commerce will soon discover the channels in which capital may more freely flow, and by which they may obtain the best returns.
J. W. Massie2

The peculiar wonder of the Hindu system is, not that it contains so much or so little true knowledge, but that it has been so skilfully contrived for arresting the progress of the human mind. To perpetuate them, is to perpetuate the degradation and misery of the people. Our duty is not to teach, but to unteach themnot to rivet the shackles which have for ages bound down the minds of our subjects, but to allow them to drop off by the lapse of time and progress of events.
Sir Charles Trevelyan 3

In prosecuting the study and in contemplating the structure of the universe, and in the consequences resulting from them, they can scarcely fail of relieving themselves from a load of prejudices and superstition; they will thus gradually, in proportion as their knowledge is spread, become better men and better subjects, and less likely ever to be made the tools of any ambitious man or fanatic.
S. Goodfellow4

We are trying to graft the science of the West on to an Eastern stem. We have raised entire sections of the community from torpor to life, and have lifted India on a higher moral plane. In proportion as we teach the masses, so we shall make their lot happier, and in proportion as they are happier so they will become more useful members of the body politic.
Lord George Curzon5

In the previous chapter, the initial phase of British colonialism leading to the introduction of modern science and technology was sketched out. The early phase represented a period when despite clearly defined interests and motives for specific projects, there was no explicitly formulated "science and technology policy" and there was constant experimentation, trial, and error. By the mid-nineteenth century, partly as a consequence of the rapid growth of science and technology in Europe in the aftermath of the Industrial Revolution, British India proved to be a good testing ground for a number of experiments in the application of science and technology by the colonial state. What followed in

nineteenth-century India was one of the largest state-sponsored scientific research and development activities undertaken in modern times. Commenting on the extent of state involvement in the scientific and public works projects, Philip Woodruff, the chronicler of British rule in India observed, "the Viceroys and their Counsellors were sometimes a trifle aghast when they contemplated how far they had gone on the road to socialism." 6As historian of science Roy MacLeod has demonstrated, British India, like Ireland and other colonies, constituted a "social laboratory," or a testing ground, for a number of policies that could be transferred to Britain and other parts of the Empire.7State-sponsored educational institutions constituted one of the channels for the diffusion of Western science and technology in colonial India, and the following section examines the debates and conflicts over the issue of education.

Diffusing Modern Science and Technology Through Education

The issue of the precise role that the East India Company should play in the sphere of education in colonial India became a major focus of contention and debate almost immediately after the acquisition of Bengal. From the perspective of the Court of Directors in London and the colonial administrators stationed in British India, the issue of the form as well as the content of education to be patronized was of singular importance. Inextricably interwined with the issue of the mode and manner of education to be patronized was the very future of colonial rule. The possible role of scientific education in creating, in the words of Lord Curzon, "useful members of the body politic,"8or as another colonial administrator put it, "better subjects, and less likely ever to be made the tools of any ambitious man or fanatic"9was evident from the beginning of colonial rule. However, the Court of Directors was also apprehensive about another possible outcome of the Company's active role in the sphere of education. In one of the earliest debates on the issue (1792), one Director observed: "we [have] just lost America from our folly, in having allowed the establishment of schools and colleges. [I]t would not do for us to repeat the same act of folly in regard to India. [I]f the Natives require anything in the way of education, they must come to England for it."10

In the debates and discussions leading up to the famous Anglicist-Orientalist controversy of 1835, the issue of the introduction of modern science and technology was central. As will be discussed below, prior to the onset of colonial rule, there was an indigenous system of education that included instruction in the sciences. In effect, the debates and discussions about the system of education to be adopted and promoted led to decisions

regarding the future of indigenous modes of instruction, especially instruction in science. The educational sphere was an important but contested arena of debate that determined what kind of science and technology would eventually be institutionalized in India. As the discussion below indicates, a combination of changing structural factors, colonial perceptions and policies, and the unintended consequences of such policies contributed to the pattern of the introduction and institutionalization of modern science and technology in colonial India. The first step in examining these issues is an historical reconstruction of the state of indigenous education in precolonial India and its decline and transformation as a consequence of specific colonial policies.

The Decline of Indigenous Education during Colonial Rule

While the remarks of the director cited above implies the lack of any indigenous system of education, colonial administrators who were actually based in British India were aware of the existence of an extensive network of indigenous schools that was slowly being destroyed. The early colonial rulers had instituted a number of surveys to enquire specifically about the extent, state, mode of instruction, and curriculum of indigenous schools. The most comprehensive and detailed surveys were conducted by William Adam in the early nineteenth century and presented to the government as *Adam's Reports on Vernacular Education in Bengal and Behar*. 11The early nineteenth-century surveys had resulted in a number of reports such as *Survey of Indigenous Education in the Province of Bombay* (18201838), G. W. Leitner's *History of Indigenous Education in the Punjab Since Annexation*, and Francis Buchanan's discussion of indigenous schools in *An Account of the District of Shahabad* (18121813).12William Adam's reports in particular had documented the existence of different types of indigenous schoolsthe *madrassas*, *pathshalas* and *mathas*,

providing instruction in Indian medical doctrines, mathematics, and other scientific subjects like Indian astronomy.13

Even as late as 1822, the governor of Madras, Thomas Munro, could declare that "every village had a school," and for Bombay presidency, G. L. Pendergest, a senior official, observed that "there is hardly a village, great or small throughout our territories in which there is not at least one school."14Most indigenous educational institutions were patronized by a system of grants in the form of rent-free land provided by the local rulers or their representatives. The revenue from these lands and properties went toward the upkeep of the educational institutions and teachers, etc. In addition to this institutionalized system of "public" patronage for education, Adams also documented the existence of private support. Reporting on the conditions prevailing in the Hughli

area near Calcutta, Adams observed that it was "a rare thing to find an opulent farmer or head of a village who had not a teacher in his employment." 15

When the British acquired the *diwani*, or the right to collect taxes, in Bengal in 1765, the rent-free lands for the support of schools represented a major loss of revenue for the Company as the Revenue Department was initially prevented from collecting any revenues from such lands. For a Company whose primary interest was in the collection of revenues to finance its trade, such land grants represented obstacles to this goal. For example, in 1837, a revenue official complained "the extent of land held rent free in Cuttuck is enormous. The tenures of that nature have been computed to be equal in value to two thirds of the Government Revenue in the District."16In the area of Cuttack alone, land worth two million rupees had been donated as an endowment for educational purposes. From the perspective of the East India Company, the allocation of tax-free land grants, a practice that had been followed in most regions for generations, appeared to be a system that perpetuated inefficiency, confusion, and even fraud. A British official described the indigenous revenue system as "a long leaky pipe with everyone taking his share," and most Company administrators perceived rent-free land endowments to be institutions deliberately designed to avoid revenue payment.17

By the late eighteenth and early nineteenth century, laws for the "resumption of land," or the right to collect revenue on previously rent-free land grants, were enacted. Lands, the revenue from which had supported schools and other institutions, were reclaimed and collection of revenue "resumed." In Bengal alone, implementation of the "resumption policy" led to an increase in revenues by five hundred thousand rupees, and in the northwestern provinces, the amount of revenue reclaimed was over 2,321,953 rupees.18By 1840, R.M. Bird, the chief revenue officer of the northwestern provinces could claim that "in almost every case in which the validity of the tenure came into issue resumption took place."19

The policy of "resumption" of rent-free land automatically led to the withdrawal of patronage for existing indigenous educational institutions like the *madrassas* and *pathshalas*. The negative impact of such changes in the revenue collection policies was evident even to the Company officials themselves. In March 1811, Lord Minto noted:

> It is a common remark, that science and literature are in a progressive state of decay among the Natives of India. The number of the learned is not only diminished, but the circle of learning, even among those who still devote themselves to it, appears to be considerably contracted. The abstract sciences are abandoned, polite literature neglected. [T]he principle cause of the present neglected state of Literature is to be traced to the want of that encouragement which was formerly afforded to it by Princes, Chieftains, and opulent individuals under the Native Government. The justness of these observations might be illustrated by a detailed consideration of the

> former and present state of Science and Literature at the three principal seats of Hindoo learning, viz., Benares, Tirhoot, and Nuddea. [W]e should have to remark with regret that the cultivation of letters was now confined to the few surviving persons who had been patronized by the Native Princes and others, under the former Governments, or to such of the immediate descendants of those persons as had imbibed a love of science from their parents. 20

Similarly, William Adam linked the destruction of indigenous education to the withdrawal of indigenous patronage. He

observed that in "at least six villages that I visited, I was told that there had been recently Bengali schools which were discontinued because the masters could not gain a livelihood."21Mr. Campbell, the collector of Bellary in Madras presidency noted:

> [I]mperfect, however, as the present education of the natives is, there are few who possess the means to command it for their children. [T]his is ascribable to the gradual, but general impoverishment of the country. It cannot have escaped the Government that of nearly a million of souls in this district, not 7,000 are now at school. In many villages where formerly there were schools, there are now none.22

Finally, in 1883, G. W. Leitner, an official posted in the Punjab region, observed, "Money had to be got out of the Punjab by fair means if possible but it had to be got. No way was so effective as the resumption of rent-free lands [T]his was the cause of the decline of indigenous education."23Not only were rent-free land grants claimed for revenue, but a number of trust funds set up by wealthy patrons specifically for instruction in classical languages was appropriated by the committee for Public Instruction and the money were used for imparting instruction in English. This happened in a number of cases, including Fazel Ali Khan's gift of over 170,000 rupees in 1829 for the study of Persian at Delhi College; a trust fund of forty thousand rupees annually by Haji Mohamud Mohsin of Hughli set up in 1835; funds allocated by Gungadhar Pundit of Agra in 1813; and the Dakshina fund of over five hundred thousand rupees for the support of indigenous education originally donated by the Maratha ruler Shivaji.24

While all the endowed lands, properties, and funds originally meant to support indigenous education were being appropriated to bolster the financially troubled East India Company, no funds were allocated by the colonial government for education until 1813. It is true that in 1781, at the request of a number of "Mahomedans of distinction," governor-general Warren Hastings had founded the Calcutta *Madrassa*, and following indigenous practice, had assigned lands valued at 29,000 rupees. Similarly, a *Hindoo Sanskrit College* had been established in 1791 at Benares by Jonathan Duncan, the Resident. The curriculum at both institutions included "Natural Philosophy, Theology, Law, Astronomy, Geometry, Mechanics, Ritual Medicine including Botany."25

Both Hastings and Duncan had initially provided for the colleges from their own resources, although the Company was eventually charged for it. However, until 1813, the East India Company had not officially authorized any expenditure for education, and no funds were spent before 1823, when the General committee of Public Instruction was constituted.

Putting British India "Beyond the Reach of Social Contingencies": Charles Grant's Observations

Although the Company had not allocated any funds for education prior to the renewal of its charter in 1813, the issue of formulating and implementing an education policy had occupied the minds of the Court of Directors ever since the acquisition of the right to collect the revenue for Bengal in 1765. The issue of scientific and technical education was central to these debates and discussions. In 1792, Charles Grant, one of the members of the Court of Directors of the Company, as well as a member of Parliament, participated in these early discussions and took issue with another member of the court who had warned against the dangers of having any educational policy after "having lost America from our folly, in having allowed the establishment of schools and colleges." 26In his *Observations On the State of Society among the Asiatic Subjects of Great Britain*,27Charles Grant questioned this view by contending that, "By planting our language, our knowledge, our opinions, and our religion, in our Asiatic territories, we shall put a great work beyond the reach of social contingencies; we shall probably have wedded the inhabitants of those territories to this country."28Being a leading member of the Clapham sect and one of the first evangelists within the colonial administration, Grant frequently invoked the designs of the "Supreme Disposer" who had put India "providentially into our hands," and posed the question, "Is it not necessary, to conclude that they were given to us, not merely that we might draw an annual profit from them, but that we might diffuse among their inhabitants, long sunk in darkness, vice and misery, the light and the benign influences of Truth, the blessings of well-regulated society, the improvements and the comforts of active industry?"29

In Grant's view, such religious objectives need not entail forsaking those secular aims that were the raison d'être of the East India Company. He argued that by following the designs of the "Supreme Disposer we shall also serve the original design with which we visited India, that design still so important to this countrythe extension of commerce."30For Grant, the objective of "serious and rational attempts for the propagation of that pure and sublime religion that comes from

God," would provide "the most rational means to remove inherent, great disorders, to attach the Hindoo people to ourselves, *to*

ensure the safety of our possessions, to enhance continually their value to us." 31The best means of achieving both these objectives would be the introduction of scientific and technical education as well as the establishment of industries. The use of coercion was ruled out as "force, instead of convincing them of their error, would fortify them in the persuasion of being right."32In Grant's proposal for pursuing these religious and secular objectives simultaneously, the diffusion of modern science and technology was accorded a pivotal role. Grant's proposal espoused a theme that recurred, albeit with minor variations, in the writings of later administrator-scholars that included Macaulay, Mill, Trevelyan and Henry Maine, and it deserves to be quoted in some detail. According to Grant,

> The true cure of darkness, is the introduction of light. The Hindoos err, because they are ignorant; and their errors have never been fairly laid before them. The communication of our light and knowledge to them, would prove the best remedy for their disorders; and this remedy is proposed, from a full conviction, that if judiciously and patiently applied, it would have great and happy effects upon them: effects honourable and advantageous for us. [T]he general mass of their opinions would be rectified and that mental bondage in which they have long been holden would gradually dissolve. To this change, the true knowledge of Nature would contribute; and some of our easy explanations of natural philosophy might undoubtedly, by proper means, be made intelligible to them. [T]he people are totally misled as to the system and phenomena of Nature: and their errors in this branch of science, upon which divers important conclusions rest, may be more easily demonstrated to them, than the absurdity and falsehood of their mythological legends. From the demonstration of true causes of eclipses the Hindoos would fall to the ground; the removal of one pillar, would weaken the fabrick of falsehood. Every branch of natural philosophy might in time be introduced and diffused among the Hindus.33

Grant went on to argue that although Indians "have improved by their intercourse with Europeans invention seems torpid among them," and "no acquisition in natural philosophy would so effectually enlighten the mass of the people, as the introduction of the principle of Mechanics and their application to agriculture and useful arts."34In an attempt to draw the attention of other members of the Court of Directors of the Company to the likely increase in revenues his policy would initiate, Grant noted that "the husbandsman of Bengal just turns up the soil with a diminutive plough, drawn by a couple of miserable cattle. [H]e thinks he is destined to this suffering, and is far more likely to die from want, than to relieve himself by any new or extraordinary effort." Ignoring the destruction and depopulation of some of the most productive agricultural lands in the wake of the Bengal famine partly precipitated by colonial revenue collection policies, Grant continued,

> What great accessions of wealth would Bengal derive from a people intelligent in the principles of agriculture, skilled to make the most of soils and seasons, to improve the existing modes of culture, of pasturage, or rearing cattle, of defence against excesses of drought, and of rain; and thus to meliorate [sic] the quality of all the produce. Horticulture is also in its first stage: the various fruits and esculent herbs, with which Hindoostan abounds, are nearly in a state of nature. In silk, indigo, sugar, and in many other articles, what vast improvements might be affected by the introduction of machinery. The skilful application of fire, of water, and of steam, improvements which would thus immediately concern the interest of the common people, would awaken them from their torpor, and give activity to their minds. 35

Grant concluded his proposal by requesting that the Company allow establishment of evangelical missions in India, which would lead to proselytism as well as the introduction of modern science and technology. In his view, the religious and secular objectives were complementary as "both in proportion as the investigation of nature, and of the character and state of man, enlarges his views of the great Creator, and his acquaintance with himself, he sees more of the suitableness of the Christian scheme, to the perfection of the one, and the condition of the other."36Finally, Grant impressed upon the Court of Directors that "were such a design to be taken up, with due zeal, by the Company, and their governments abroad, the expense and labour would assuredly be repaid in the end, probably by specific returns, but certainly by the

augmentation of the agriculture and commerce of the country, and the general effects upon society."37

Renewal of the Charter of the Company (1813) and an Education Policy for British India

Charles Grant's specific proposal for the "modernization" of Indian society and the introduction of modern science and technology through the medium of missionary activity was challenged from a number of quarters. However, the essence of his argument, without the evangelical religious fervor, was restated a few decades later by James Mill and Thomas B. Macaulay. The activities of the missionaries were strongly curtailed by the Company. When the renewal of the charter of the Company was being considered in 1813, a number of members of Parliament and ministers who constituted a "Committee of the Protestant Society," convened a meeting at the New London Tavern and appealed to the Parliament, that

> as Men, as Britons, and as Christians, this committee continue to regard with anguish, the moral depression and religious ignorance of very many

> millions of immortal beings who people the plains of India, subject to British power. [C]onvinced by history, observation, and experience, that Christianity would affirm inestimable benefits, and that their diffusion is practicable, wise, and imperative, they cannot but persevere eminently to desire its speedy and universal promulgation throughout the regions of the East." 38

A number of such meetings were held, but their views were challenged by John Bebb, an influential director of the Company.

In his letter to the Court of Directors, John Bebb expressed strong concern over the attempt by some members of Parliament and some cabinet ministers to expand the church establishment and allow unrestricted missionary activity in India. Referring to past incidents of "violent irritation in the minds of the natives of India, from apprehension of their religious opinions being molested," Bebb contended that "should the Brahmin and other religious men conceive their religion to be in danger, the alarm will soon catch the native soldiery." Invoking the "Romans, [who] on the acquisition of their vast dominions, molested not the religions of the countries they conquered [while] the latter Emperors pursued a different system of policy, and accelerated the fall of their empire," Bebb argued that "the principal Mahomedans many of them as enthusiastic as any of our own zealots [would] unite with and inflame the Hindoos against the Christians." Reminding the Court of Directors of the "nearly twenty-eight years" he had spent in India, Bebb warned the Company that "among the causes which may produce or accelerate the downfall of the British authority in India, may be reckoned a spirit of proselytism, manifesting itself in endeavours to convert the natives of India subject to the Company's authority." He criticized the views of Charles Grant and other evangelists, contending that, "when minds take a certain bias, they pervert, bend and twist everything to their particular object; defects in the moral character of the people of India, arising out from political have been attributed to religious causes." Finally, Bebb relented somewhat in his criticism of the evangelists:

> If, however, Parliament should be earnestly desirous of placing the Church Establishment in India under the superintendence of a bishop and archdeacons, let the measure be delayed until times more suited to it than the present; until a perseverance in our former line of conduct shall have restored the confidence of the natives of India, and have caused the recent irritations to be completely forgotten, until the fervour which has possessed the minds of many men in this country be moderated, until the finances of India be better able to bear the expense than they now are, and until the descendants of the English in India be considerably increased in number.39

One consequence of the objections of Bebb and others was that the very first resolution on the educational policy of the Company, passed in 1813, and

conveyed to the governor-general, endeavored to strengthen the indigenous system of education, or what was left of it, at the newly established *madrassa* in Calcutta and the *Hindoo* Sanskrit College in Benares. In principle, the education

policy resolution of 1813 followed Lord Minto's "Minute 1811 on Education." Minto had traced "the principle cause of the present neglected state of Literature in India to the want of that encouragement which was formerly afforded to it by Princes, Chieftains and opulent individuals under the Native Government," and had recommended "a plan necessary to be adopted for the restoration of Hindu science and literature and similar arrangements for the revival of Letters among our Mahomedan subjects." 40

The 1814 dispatch on education to the governor-general allocated a sum of ten thousand pounds sterling annually for support of education along the indigenous model. The dispatch called for the encouragement of indigenous literature and science, because "there are in the Sanscrit language many tracts of merit on the virtues of plants and drugs, and on the application of them in medicine, the knowledge of which might prove desirable to the European practitioner. [T]here are treatises on Astronomy and Mathematics, including Geometry and Algebra, which though they may not add new lights to European science, might be made to form links of communication between the natives and the gentlemen in our service." Overall, the dispatch contended that "we shall consider the money that may be allotted to this service as beneficially employed, if it should prove the means, by an improved intercourse of the Europeans with the Natives, to produce those reciprocal feelings of regard and respect which are essential to the permanent interests of the British Empire in India."41From the dispatch it is evident that research by members of the Asiatic Society on indigenous science, which had already been published in its journal, *Asiatic Researches*, was being noticed in Britain.

In 1823, the government instituted a committee on Public Instruction at Calcutta to investigate the best mode of imparting instruction. The money authorized earlier was placed at the disposal of the committee on Public Instruction, which was regarded as the sole institutional authority for advising the colonial government on policies relating to public education. The committee was composed of members from the colonial administration who held diverse opinions, regarding the direction public education under state patronage ought to take. Some, like H. T. Prinsep, an active member of William Jones's Asiatic Society, believed that the best mode of introducing Western science and technology in India was through the establishment of institutions on the indigenous models of the *madrassas* and *vidyalayas*, where instruction could be imparted in the vernacular, and the curriculum could include what was left of indigenous science. There were others who, following Charles Grant, believed that there was nothing worthwhile in indigenous knowledge and institutions, and favored instruction in English and the withdrawal of any

state patronage for Sanskrit, Persian, and Arabic. These divergent views were to crystallize later into the "Orientalist" and "Anglicist" factions within the committee that eventually led to the "Anglicist-Orientalist" controversy of 1835 and the (in)famous "Minute on Education" by Thomas Babington Macaulay.

The Indian Response to State-sponsored Education

While these issues were being debated both within England and India, a section of Indians had established colleges to promote instruction in English language, literature, and Western sciences. A number of factors contributed to this action. Over seven decades of colonial rule and years of trade by the Company prior to 1765 had initiated a number of changes that had transformed the structure of Indian society. Extensive inland trade had, over a period of time, intertwined the fortunes of Indian merchants with those of the Company, which in turn, had partly facilitated the British conquest of Bengal in 1764. After the Battle of Plassey, Cornwallis' Permanent Settlement had facilitated large-scale sale of land on the market, which had encouraged the development of an Indian urban landlord class and the elite "gentry," or *bhadralok*. Many traditional landowners who were unable to pay the revenue fixed under the Permanent Settlement Act, had forfeited their land, which was then purchased by the merchants who had earlier benefited from the Company's trade. While Bengal was rapidly depopulated in the aftermath of the famine of 1770 and its agriculture destroyed partly as a consequence of the Permanent Settlement, a section of the Indian population had benefited enormously from the same policies. Over a period of time, a new urban elite had emerged that sought employment in the simultaneously expanding British administration. 42Although the Permanent Settlement had been implemented in Bengal, a similar process was at work in the Madras and Bombay presidencies. In Madras presidency, for example, growing numbers of erstwhile *dubash* entrepreneurs moved to the city to create a "magnate class less dependent on trade and more dependent on office and rents."43

The response of the emergent urban middle classes has to be understood in the context of such structural transformations of Indian society. It was the representatives of the *bhadralok* in Bengal, who, at their own initiative, established colleges

for teaching English language, literature, and Western science. In 1816, influential members of the *bhadralok* gathered to found the Calcutta Hindu College, or *vidyalaya*, for this purpose. Although started by funds donated by Indians, the colonial government also contributed financially, and the institution was managed by a joint committee of Indians and Englishmen.

Similar institutions were established in a number of regions at the initiative of wealthy Indian patrons. One Joynarain Ghossal provided funds for another college that was founded in Benares in July 1818, and between 1821 and 1823, many other colleges were established in Bombay presidency. In the colleges of Bombay presidency, the colonial government offered financial support, and members of the administration were also actively involved through the Bombay Native School-Book and School Society that sponsored these institutions.

These changes, together with the perception of the colonial administrators of the need for a workforce to staff the burgeoning bureaucracy and the desire "to produce those reciprocal feelings of regard and respect which are essential to the permanent interests of the British Empire in India," 44led to state involvement in education. When in 1821 a distinguished "Orientalist," H. H. Wilson, acting on the earlier "Minute on Education" by Lord Minto (1811) established the Hindu Sanskrit College at Calcutta on the pattern of the Benares Hindu College, the response from Raja Ram Mohun Roy, a representative of the rising *bhadralok* of Calcutta, was immediate. Lord Minto in his "Minute of 1811" had pointed out that "the prevalence of the crimes of perjury and forgery is in a great measure ascribable, both in the Mahomedans and Hindus, to the want of due instruction in the moral and religious tenets of their respective faiths,"45and Wilson's move to establish a Sanskrit college represented, in part, an attempt to fulfill those aims.

Raja Ram Mohun Roy's "Memorial" and the Anglicist-Orientalist Controversy of 1835

There was immediate reaction to the proposal to fund a Sanskrit college. Raja Ram Mohun Roy's strong protest against the establishment of the Sanskrit college, communicated in a "memorial" to Lord Amherst, reflected the concerns of the emergent Bengali *bhadralok* in the context of a society transformed by decades of colonial rule.

Arguing that "the present rulers of India cannot easily become so intimately acquainted with their real circumstances as the natives of the country are themselves," and that "we should, therefore be guilty of a gross dereliction of duty to ourselves [if we fail] to supply them with such accurate information as might enable them to devise and adopt measures calculated to be beneficial to the country," Roy contended,

> When this seminary [the Sanskrit school] of learning was proposed we were filled with sanguine hopes that this sum would be laid out in employing European gentlemen of talents and education to instruct the natives of India in mathematics, natural philosophy, chemistry, anatomy, and other

> useful sciences. We already offered our thanks to Providence for inspiring the most generous and enlightened nations of the West with the glorious ambition of planting in Asia the arts and sciences of modern Europe. This seminary (similar in character to those which existed in Europe before the time of Lord Bacon) can only be expected to load the minds of youth with grammatical niceties and metaphysical distinctions, of little or no practical use to the possessors or Society. The Sangscrit language, so difficult that almost a lifetime is necessary for its acquisition, is well known to have been for ages a lamentable check on the diffusion of knowledge. [T]he Sangscrit system of education would be the best calculated to keep this country in darkness, if such had been the policy of the British Legislature. But as the improvement of the native population is the object of the Government, it will consequently promote a more liberal and enlightened system of instruction; embracing mathematics, natural philosophy, chemistry, anatomy, and other useful sciences, which may be accomplished with the sum proposed, by employing a few gentlemen of talents and learning, educated in Europe, and providing a College furnished with the necessary books, instruments, and other apparatus. 46

Although Ram Mohun Roy protested strongly against the establishment of the Hindu Sanskrit College at Calcutta, the

goals of setting up the Sanskrit college were not at variance with his own ideas. As far as the colonial administrators were concerned, the raison d'être for establishing the Hindu college was the introduction of modern science and technology. What Roy and those he represented objected to was the strategy and mode of achieving this common objective.

At this juncture, imperial rule was fragile and the Orientalist faction of the General committee of Public Instruction was extremely apprehensive of arousing the hostility of the Brahmans of Bengal. The committee did not want the Company to be perceived as interfering with their religious authority and the establishment of the Hindu Sanskrit College was perceived by the Orientalists as one strategy of coopting and using the agency of the Brahmans who were designated "natural leaders" in the sphere of education, for diffusing knowledge of modern science and technology. One of the ways of ensuring the cooperation of native agency was to use Sanskrit instead of English as the medium of instruction. This mode of reasoning is evident from the letter of the General committee of Public Instruction to the Court of Directors, dated October 6, 1823. According to this letter, "the diffusion of sound practical knowledge amongst the able and respectable individuals, of whom its members will consist of men, who by their Brahmanical birth, as well as by their learning, exercise a powerful influence on the minds of every order of the community, cannot fail to be attended with beneficial effects." In recommending instruction in Sanskrit, the committee argued that "the chief advantages are, that as the connexion will be effected in an unobtrusive manner, it will not likely, in the first instance, give any alarm to the prejudices of the Brahmanical

members of the college." The plan of the committee was to impart instruction in both indigenous and European sciences in the hope that "the union of European and Hindu learning being thus quietly effected in one case, it will hereafter be comparatively easy to carry the combination into other departments, and the improved cultivation of science, and literature may be thus successfully and extensively promoted." The committee explicitly proposed that "instructions to be given by the professor of experimental philosophy, attached to the Government and the native Hindu Colleges, shall embrace the following sciences: Mechanics, Hydrostatics, Pneumatics, Optics, Electricity, Astronomy, Chemistry." 47

In terms of overall goals of public education, the aims of Ram Mohun Roy and the Committee of Public Instruction were not at all at odds with each other. Since the members of the committee had spent years in India and were well versed in its classical languages, they were even better acquainted with the local circumstances than the Court of Directors based in London. In a dispatch drafted by James Mill, who was by then employed at the India Office, the directors expressed concern over the proposed Hindu college. Mill's utilitarian philosophy as well as the development of his views on India, expressed forcefully in his *History of British India* are clearly evident in the dispatch of February 1824:

> With respect to the sciences it is worse than a waste of time to employ persons either to teach or to learn them in the state in which they are found in the Oriental books. [W]hat remains in Oriental literature is poetry; but it has never been thought necessary to establish colleges for the cultivation of poetry. [W]e apprehend that the plan of the institutions to the improvement of which our attention is now directed was originally and fundamentally erroneous. The great end should not have been to teach Hindoo learning, but *useful* learning. In professing to establish seminaries for the purpose of teaching mere Hindoo, or mere Mahomedan literature, you bound yourselves to teach a great deal of what was frivolous, not a little of what was purely mischievous and a small remainder indeed in which utility was in any way concerned.48

Despite the strong language of the dispatch, Mill concluded on a conciliatory note by agreeing with the committee that "in the institutions which exist on a particular footing alterations should not be introduced more rapidly than a due regard to existing interests and feelings will dictate." But this conciliatory afterthought was immediately qualified by the recommendation that "at the same time incessant endeavours should be used to supersede what is useless, or worse."49

The General committee of Public Instruction responded to the above criticisms in a letter (August 18, 1824) to Governor-General Amherst by impressing upon him that the ultimate goal of their plan for public instruction was not dissimilar to what was envisaged by the Court of Directors. However they

pointed out that in order to achieve similar objectives, considerable tact had to be exercised as

> although we believe the prejudices of the natives against European interference with their education in any shape, are considerably abated, yet they are by no means annihilated, and might very easily be roused by any abrupt and injudicious attempts at innovation, to the destruction of the present growing confidence from which, in the course of time, the most beneficial consequences may be expected.

They particularly emphasized the fact that "every one in the habit of communicating with both the learned and unlearned classes, must be well aware, that generally speaking, they continue to hold European literature and science in very slight estimation." The course of action envisaged by the "Orientalist" faction of the committee was to introduce instruction in Western science and technology through the agency of the Indians themselves. They argued that the implementation of such a policy would be considerably more effective than the one proposed by James Mill in the form of the dispatch from the Court of Directors. As they put it, "we must qualify the same individuals highly in their system as ours, in order that they may be as competent to refute errors as to impart truth, if we would wish them to exercise any influence upon the minds of their countrymen." In a specific rebuttal of the court's dismissal of indigenous sciences, the committee contended, after a qualifying preamble, "without wishing to enhance the value of Oriental studies beyond a fair and just standard," that "the metaphysical sciences, as found in Sanscrit and Arabic writings, are, we believe, fully as worthy of being studied in those languages as in any other. [T]he arithmetic and algebra of the Hindus lead to the same principles as those of Europe and in the Madressa, the elements of mathematical science, which are taught are those of Euclid." They concluded their letter by reminding Governor-General Amherst that

> we must for the present go with the tide of popular prejudice [of the natives] and we have the less regret in doing so, as we trust we have said sufficient to show that the course is by no means unprofitable. [We shall] avail ourselves of every favorable opportunity for introducing them [European sciences] when it can be done without offending the feelings and forfeiting the confidence of those for whose advantage their introduction is designed."
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In representing their views to Governor-General Amherst, the committee was reinforcing the views of Monstuart Elphinstone, the governor of Bombay presidency, who, while recommending a plan to "communicate our own principles and opinions by the diffusion of a rational education," had warned about "the dangers to which we are exposed from the sensitive character of the religion of the Natives, and the slippery foundations of our Government, owing to the total separation between us and our subjects."51

James Mill, Utilitarianism as a "Militant Faith," and Macaulay's "Minute on Education"

By the time William Bentinck was appointed governor-general of India in 1828, British rule was perceived to be relatively more secure than it had been just a few years earlier. James Mill had acquired a position of power within the East India Company and was subsequently promoted to the position of the chief examiner in 1830. Mill's magisterial *History of British India*, which according to one scholar was instrumental in transforming utilitarian philosophy into a "militant faith," had become the standard textbook for Company officials training for administrative positions in India at the Company's administrative college at Haileybury. 52In his *History of British India*, James Mill had directly criticized the work of William Jones and other "Orientalists" who had spent many years in India. Indeed Mill argued that the very fact that he had never spent any time in India qualified him to provide a more objective appraisal of its culture and civilization than those who were immersed in it. Contending that "as soon as everything of importance is expressed in writing, a man who is duly qualified may obtain more knowledge of Indian in one year in his closet in England, than he could obtain during the course of longest life, by the use of his eyes and ears in India," James Mill criticized all aspects of Indian civilization from a utilitarian perspective. His harshest polemic, was reserved for the state of Indian science and technology:

> The *Surya Siddhanta* is the great repository of astronomical knowledge of the Hindus. [T]his book is itself the most satisfactory of all proofs of the low state of the science among the Hindus, and the rudeness of the people from whom it proceeds. The observatory at Benares, the great seat of Hindu astronomy and learning, was found to be rude in structure, and the instruments with which it was provided was of the coarsest contrivance and construction. Exactly in proportion as *Utility* is the object of every pursuit, we may regard a nation as civilized.

> According to this rule, the astronomical and mathematical sciences afford conclusive evidence against the Hindus. They have been cultivated exclusively for the purposes of astrology; one of the most irrational of all imaginable pursuits; one of those which most infallibly denote a nation barbarous; and one of those which it is most sure to renounce, in proportion as knowledge and civilization are attained.53

Although Mill was a philosophical radical and, together with Jeremy Bentham, opposed colonialism, British India was never perceived to be a "colony" as Canada and Australia were. By that time, almost all of the British in India were employed by the Company or the Crown and were expected to return home. Until 1833, the Company had the right to control migration to India by license, and, in fact, the presence of private or "nonofficial"

Europeans was viewed as politically dangerous. 54Such a social setting hardly constituted a "colonial" society in the strict sense of the term, and this distinction was clearly reflected in the administrative division of labor in England. There was an India Office to deal exclusively with the administration of India, and a Colonial Office for all the other colonies.

One of Mill's objectives in writing the *History of British India* was to clarify the theoretical assumptions of utilitarianism, an exercise that followed from his belief that "good practice can, in no case, have any solid foundation but in sound theory."55As Javed Majeed has pointed out, Mill's work on India attempted to formulate a theoretical basis for a liberal program to emancipate India from its own culture. In so doing, Mill also wanted to extend Bentham's ideas as outlined in his *Essay on the Influence of Time and Place in Matters of Legislation* (1793). Bentham had wanted to test his theory that it was possible to arrive at a rational set of laws universally applicable, irrespective of time, culture, and social context. According to Bentham, Bengal constituted an ideal setting for the testing of his theory as it was a society that was culturally quite different from England.56Mill's utilitarian philosophy had led him to the conviction that one could deduce rational principles for restructuring societies, which could then be implemented universally without regard for local variations. Unable to put his own or Bentham's ideas in practice in "priest-ridden, lawyer-ridden, lord-ridden, squire-ridden, soldier-ridden" regions of Britain, Mill found British India to be an ideal testing ground for his utilitarian theories.

As Javed Majeed57has argued, Mill's writings on India constituted self-reflexive texts: By criticizing Indian society, he was simultaneously criticizing British society. In the appointment of William Bentinck as the governor-general to India, he found a powerful ally to put some of his theories in practice. And in personally defining the new post of legal member of the Governor-General's Council and then recommending the appointment of Thomas Babington Macaulay for the position, Mill ensured strong support for his institutional experiments in India.58Bentinck's remark to Mill that, "I am going to British India, but I shall not be Governor-General; it is you who will be Governor-General," was supported by Bentham's claim that "Mill will be the living executiveI shall be the dead legislature of British India."59While Mill's primary but not exclusive interest was in the application of rational legal principles"India will be the first country on earth to boast a system of law and judicature as near perfection as the circumstances of the people would admit"60the policies of Macaulay and Bentinck had significant consequences for the future development of science and technology in India. The Company had also appointed Thomas Malthus to the very first chair in political economy in Britain, at its college at Haileybury. The future administrators of British India who trained at Haileybury were well versed in the emerging view that the problem of constructing an efficient government could be solved through the new science of political economy.61

In 1833 the East India Company's charter was renewed, together with an act that stipulated "that no native of the said territories, nor any natural-born subject of His Majesty, resident therein, shall, by reason only of his religion, place of birth, descent, colour, or any of them, be disabled from holding any place, office, or employment under the said Company." 62By this time, the Company was involved extensively in the administration of Indian territories directly under its control, and the issue of obtaining Indians for the lower rungs of administration had emerged as a major issue. One of the ways of solving the problem of the shortage of Indians for various levels of the administration was the expansion of education in English. Already in 1830, the Court of Directors had informed the governor-general that

> there is no point of view in which we look with greater interest than as being calculated to raise up a class of persons qualified, by their intelligence and morality, for high employments in the Civil Administration of India. [A]s the means of bringing about this most desirable object, we rely chiefly on their becoming, through a familiarity with European literature and science, imbued with the ideas and feelings of civilized Europe.

Furthermore, a major change in the policy was also initiated with the dispatch of 1830. The dispatch read: "With a view to giving the Natives an additional motive to the acquisition of the English language, you have it in contemplation gradually to introduce English as the language of public business in all its departments; and you have determined to begin at once by adopting the practice of corresponding in English with all Native Princes or persons of rank who are known to understand the language." The Court of Directors expressed its "anxious desire to have at our disposal a body of Natives, qualified, by their habits and acquirements, to take a larger share, and occupy higher situations in the Civil Administration of their country, than has hitherto been the practice under our Indian Government."63

In the following year (1831), the committee of Public Instruction submitted a report documenting the success of their policy designed not to provoke the "native prejudices" of the Indians, a policy, which according to them, was proving to be successful in the cautious introduction of modern science and English in the curriculum. Thus, "in the *Madrissa*, Euclid has been long studied, and with considerable advantage: European anatomy has also been introduced. In the Sanskrit College of Calcutta, European anatomy and medicine have nearly supplanted the native systems." They reported that "without offering therefore any violence to native prejudices, and whilst giving liberal encouragement to purely native education, the principle of connecting with the introduction of real knowledge had never been lost sight of. [A] command of the English language, and a familiarity with its literature and science have been acquired to an extent rarely equalled by any schools in Europe."64

It was in the context of the growing need for Indians in the lower administrative positions, and the increasing demand for English education from the

members of the *bhadralok* seeking employment, that T. B. Macaulay arrived in India in 1834. By this time, the Court of Directors in London as well as Governor-General Bentinck in India had already decided to introduce English as the medium of communication in the administration. Soon after Macaulay's arrival, the existing difference of opinion within the committee of Public Instruction had been further polarized over the issue of whether English or the vernacular constituted the best medium for the propagation of European science. Up until the appointment of Macaulay, the "Orientalist" faction, which included such senior members as H. T. Prinsep and H. H. Wilson, was in a dominant position within the committee, while the "Anglicist" faction consisted of younger members without a leader. With the appointment of T. B. Macaulay as the president of the General Committee of Public Instruction, the Anglicist faction found a spokesman whose views were shared by Governor-General Bentinck, James Mill, and the Court of Directors in England. The constant dispute between the two factions culminated in the famous and oftcited "Minute on Education" delivered by Macaulay on February 2, 1835. Macaulay's minute specifically recommended the extension of official patronage for instruction in English and Western science and the withdrawal of funds for education in Sanskrit, Arabic, or Persian. The resolution of this controversy had significant consequences for the trajectory of the future development of science and technology in India.

Reflecting the strong influence of James Mill and Charles Grant on his thinking, Macaulay argued:

> The question now before us is simply whether, when it is in our power to teach this language, we shall teach languages in which, by universal confession, there are no books on any subject which deserve to be compared to our own, whether, when we can teach European science, we shall teach systems which, by universal confession, wherever they differ from those of Europe differ for the worse, and whether, when we can patronize sound philosophy and true history, we shall countenance, at the public expense, medical doctrines which would disgrace an English farrier, astronomy which would move laughter in girls at an English boarding school geography made of treacle and seas of butter. We are a board for the wasting the public money, for printing books which are of less value than the paper on which they are printed was while it was blankfor giving artificial encouragement to absurd history, absurd metaphysics, absurd physics. 65

Macaulay urged the government to "strike at the root of the bad system which has hitherto been fostered by us," by

putting an end to official patronage for the printing of Sanskrit and Arabic books and the abolition of the *madrassa* and Sanskrit College at Calcutta. In his note of protest against Macaulay's minute, H. T. Prinsep reiterated the Orientalist position by warning the government against committing itself "irretrievably to measures hateful and injurious

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to the mass of the people under its sway such as it might repent afterwords when too late." Not disagreeing with Macaulay's opinion about the superiority of English knowledge, Prinsep reformulated the issue as "the whole question ishave we it in our power to teach everywhere this English and this European science? It is in doubting nay in denying this that those who take the opposite view maintain the expediency of letting the natives pursue their present course of instruction and of endeavouring to *engraft* European science." He reiterated a familiar theme when he contended that

> by following this course we bind and perpetuate no enmities but on the contrary mitigate and reconcile opinions and doctrines that seem adverse and when we recollect that out of the schools the same philosophy that is the highest point of knowledge in Arabic and Sanscrit grew the very philosophy we wish to inculcate, *viz.*, that of Bacon and Locke and Newton, why should we despair of engrafting of the similar stock of Arabia and India a similar fruit? 66

In the changed social and ideological circumstances, the Anglicists' views, conveyed forcefully by Macaulay, prevailed and, barely, a month later, Governor-General Bentinck's resolution called for the suspension of government funds for the *madrassa* and the Sanskrit College, as well as for the "printing of Oriental works." Bentinck also withdrew financial support for students at the indigenous schools and recommended that "all the funds that these reforms will leave at the disposal of the committee be henceforth employed in imparting to the native population a knowledge of English literature and science through the medium of English language."67

While Macaulay's claim that increasing numbers of Indians were demanding education in English and science was accurate, there were members of the developing strata whose life chances were linked to knowledge of English. Such a development was reinforced by the enactment of policies that had introduced English as the medium of communication in the lower levels of the colonial administration. However, not all Indians were in favor of such changes in the mode of education and H. T. Prinsep noted in his diary that within three days of Macaulay's minute, "a petition was got up signed by no less than 30,000 people on behalf of the Madrassa and another by the Hindus for the Sanskrit College."68These changes in the educational sphere, influenced by James Mill's utilitarian philosophy, were introduced at a time when members of the colonial administration felt more secure and confident and felt they no longer need fear any hostility from the Indian elites.

The Orientalist faction, aware of the changed social circumstances, pleaded only for the continuation of existing indigenous institutions of learning and limited funds for the publication of Indian books, a demand that was granted in 1839 by the successor to Bentinck, governor-general Auckland. By this time the involvement of the Company in administration had expanded

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considerably, and Auckland sanctioned 24,000 pounds per annum for public education, an amount that he thought was not excessive, considering that Bengal presidency was providing a "revenue of over 13 millions" per year. As compared to 24,000 pounds for English literature and science, only three thousand were promised for the maintenance of existing institutions for indigenous instruction.

Charles Wood's educational dispatch of 1854, finally settled the Anglicist-Orientalist controversy and set the goals and direction of state-sponsored education in unambiguous terms. While not wishing to "diminish the opportunities which are now afforded in special institutions for the study of Sanskrit, Arabic and Persian literature," Wood's dispatch argued, "the systems of science which form the learning of the East abound with grave errors. Asian learning, therefore, however widely diffused, would but little advance our object." The object of the educational dispatch was specified as "the diffusion of the improved arts, science, philosophy and literature of Europe; in short of European knowledge." 69This objective was important because

> this knowledge will teach the natives of India the marvellous results of the employment of labour and capital, rouse them to emulate us in the development of the vast resources of their country, guide them in their efforts and gradually, but certainly, confer upon them all the advantages which accompany the healthy increase of wealth and commerece; and, *at the same time, secure to us a larger and more certain supply of many articles necessary for our manufacture and extensively consumed by all classes of our population, as well as an almost inexhaustible demand for the produce of British labour*."70

The connection between instruction in science and technology and the emergence of a capitalist colonial state is quite evident. Wood's dispatch of 1854 led to the creation of Education Departments in each of the provinces under the control of a central authority and to the founding of three universities at Calcutta, Bombay, and Madras in 1857. These were followed by the establishment of the Universities of Punjab and Allahabad in 1882 and 1887 respectively. From this point on, financial support for indigenous schools declined rapidly, and by the turn of the century, these institutions had disappeared almost completely.71

Marquess Dalhousie, Public Works, and Technical Education

Although a number of surveys had been initiated in the early phase of colonial rule, these projects had been uncoordinated and, more often than not, local administrators had a difficult time persuading the Court of Directors of the

benefits of such public works for a trading company. By the mid-nineteenth century, the influence of utilitarian philosophy, structural changes initiated by colonial administration, and imperial perceptions led to the incorporation of state-sponsored public works as an integral aspect of governmental policy. The first half of the nineteenth century witnessed the initiation a number of gigantic public works that led to state involvement in the application of science and technology and culminated in the creation of a Public Works Department for the government of India in 1854. The creation of the Public Works Department coincided with Wood's educational dispatch of 1854 and indicated a shift in the official policy that had previously viewed public works, as a colonial administrator put it, as "an unavoidable evil, to be undertaken only when it could not be postponed any longer, and not, if possible, to be repeated." 72

However, declining revenues, partly as a consequence of early colonial policies, and increasing financial problems for the Company led to an interest in public projects such as irrigation in order to generate revenues through higher agricultural productivity. In addition to such pressing economic imperatives, the execution of a wide range of public works through the application of science and technology was also perceived as being invaluable for legitimizing colonial power in a situation where there was tremendous dislocation of the agrarian social structure due to specific colonial policies. As Arthur Cotton, an early and enthusiastic proponent of the application of science and technology argued, increased public works and subsequent material improvements would constitute the most "legitimate way of consolidating our power" in India.73

The initial impetus for repairing the ruined irrigation systems and the construction of new canals was the rapid decline in revenue due to recurring famines. The large number of gigantic irrigation projects initiated in the first half of the nineteenth century required a larger supply of skilled engineers than was available through the Company's services. As canal irrigation was not common in England, the Company had to train civil engineers who would help in the construction and maintenance of canals and other irrigation works in India. One particularly gigantic undertaking was the Ganga Canal project, which required a large pool of engineers who were skilled both in engineering and in Indian languages to communicate with the large numbers of Indian laborers employed in its construction. It was the Ganga Canal project that led to the expansion of an informal engineering school established by Lt. Baird Smith at Roorkee in 1845.74In 1847, the institution was expanded considerably and renamed the Thomason Civil Engineering College, and its success in preparing engineers essential for the execution of public works projects was commented upon extensively in Charles Wood's dispatch of 1854.

In the context of the urgent need for engineers, the Thomason Civil Engineering College at Roorkee provided a model for similar institutions, and

such a development was in accord with government policy as enunciated in Wood's dispatch. Referring to the college, the dispatch had specifically recommended that "now that the system of railways and public works is being rapidly extended it is expedient that similar places for practical instruction in civil engineering should be established in other parts of India. [W]e trust that immediate measures will be taken to supply a deficiency which is, at present but too apparent." 75A number of institutions were in fact established at Calcutta, Poona, and Madras, and these engineering colleges represented an innovation in the history of British technical education. Up until the end of the nineteenth century, England had no formal institutions imparting technical education, and engineers received their training as apprentices. The engineering colleges established in colonial India provided the models for replication in England in the late nineteenth century, and the colonial encounter contributed to the development of technical education in Britain.76

In addition to the belated repair of the ruined irrigation systems and the construction of new canals, the mid-nineteenth century also witnessed the execution of a number of other public projects under the tenure of Marquess Dalhousie (18481856). The ideological ground for these undertakings had already been cleared by the utilitarianism of James Mill and Jeremy Bentham, and the necessary administrative groundwork had been prepared by Dalhousie's predecessor, William Bentinck. Bentinck had earlier declared that the introduction of steamboats into India would revolutionize transport and communications and would serve as the "great engine of moral improvement" in a country "cursed from one end to the other by the vice, the ignorance, the oppression, the despotism, the barbarous and cruel customs that have been the growth of ages under every description of Asian misrule."77Borrowing Bentinck's metaphor, Dalhousie, who was an ardent disciple of Bentham, declared that the railways, telegraphs, and an organized and uniform postal system were the "three great engines of social improvement" in India.78However, it would be a mistake to assume that such enthusiasm for the railway as an agent of social change or moral improvement was reserved by the British exclusively for India. Earlier, the railways had captured the imagination of British people of letters. William Thackeray, for example, had suggested that railway tracks provided the "great demarcation line between past and present," while Alfred Tennyson, after observing a passing train, wrote "let the great world spin forever down the ringing grooves of change." Finally, J. W. Turner's painting *Rain, Steam and Speed* (1844) constituted a visible symbol of the "Victorians' exhilaration at the power of the railway."79Although similar views prevailed in both countries, the crucial difference was that in India, the railways were introduced in a colonial setting.

The major public works undertaken under Dalhousie's rule included the introduction of railways (1849), the telegraph (1852), and extensive reorganization of the postal system (1850). Finally, the public works were themselves

placed on a more organized footing with the establishment of a separate Public Works Department for the Government of India in 1854. Although the introduction of the railway in India was conceived, literally, as an "engine" of moral improvement and modernization, such considerations were linked to the economic and military imperatives of the Empire.

The major factor that contributed to the introduction of the railways in India was pressure from the cotton manufacturers of Britain, who were affected by the American "cotton famine" of 1846, and were in urgent need of supplies of staple for their mills. 80However, transportation from the cotton-growing regions of the Deccan to the harbors was slow and difficult, and the Lancashire industrialists saw the construction of a railway line from Bombay to the cotton plantations as "nothing more than an extension of their own line from Manchester to Liverpool."81Charles Wood, a strong ally of the Lancashire industrialists and the president of the Board of Control that oversaw the activities of the East India Company, wrote to Dalhousie in India: "If we could draw a larger supply of cotton from India it would be a great national object. It is not a comfortable thing to be so dependent on the United States. If we had the Bombay railway carried into the cotton country it would be the great work which Government is capable of performing with a view to this end."82At the same time, influential British entrepreneurs and engineers like Rowland M. Stephenson had proposed elaborate schemes for railway lines linking Calcutta, Delhi, Madras, Bombay, and Calicut, and had urged the Company to subsidize railway construction in India. Stephenson argued,

> The first consideration is as a military measure for the better security with less outlay, of the entire territory, the second is a commercial point of view, in which the chief object is to provide the means of conveyance from the interior to the nearest shipping ports of the rich and varied productions of the country, and to transmit back

> manufactured goods of Great Britain, salt etc., in exchange.83

The strategic and military significance of the railways was evident to Dalhousie, who in his 1853 "Minute to the Court of Directors" observed that the railroads would provide "full intelligence of any event to be transmitted to Government at five times the speed now possible; as well as the concentration of its military strength on every given point, in as many days as it would now require months to effect."84Hyde Clark, another lobbyist for the Indian railways sought to allay the fears of the Company to undertake investments in such a gigantic enterprise by pointing out that "the real operation, after all, is to make the Hindoos pay for the railways, and enable us to reap a large portion of the profits."85

Dalhousie was convinced of the economic significance of the railways for England, and his views were articulated in his 1853 "Minute on the Railway." He contended:

> The commercial and social advantages which India would derive from their establishment are, I truly believe beyond all present calculation. Great tracts are teeming with produce they cannot dispose of. England is calling aloud for the cotton which India does already produce in some degree (sic!) and would produce sufficient in quality, and plentiful in quantity if only there were provided for the fitting means of conveyance for it from distant plains to the several ports adopted for its shipment. Every increase of facilities for trade has been attended, as we have seen, with an increased demand for articles of European produce in the most distant markets of India. 86

In addition to such economic and strategic interests, missionaries and some administrators were also convinced that the railways would eventually destroy the caste system and the religion of the people, facilitate their conversion to Christianity, and eventually lead India on the road to "modernization." These interconnected themes were well articulated by Dalhousie's biographer Edwin Arnold who observed,

> Those who have travelled on an Indian line, or loitered at a Hindoo railway station, have seen the most persuasive missionary at work that ever preached in the East. Thirty miles an hour is fatal to the slow deities of paganism, and a pilgrimage done by steam causes other thoughts to arise at the shrine of Parvati or Shiva than the Vedas and Shastras inculcate. The Hindoo sees many villages and hills now beside his own; he travels, that is, he learns, compares, considers and changes his ideas.87

This theme of the railways as an agent of "modernization" was more explicitly expressed by W. A. Rogers, an officer in the Indian Civil Service, who declared:

> Railways are opening the eyes of the people who are within reach of them in a variety of ways. The teach them that time is worth money, and induce them to economise that which they had been in the habit of slighting and wasting; they teach them that speed attained is time, and therefore money, saved or made. They introduce them to men of other ideas, and prove to them that much is to be learnt beyond the narrow limits of the little town or village which has hitherto been the world to them.88

Finally, Karl Marx's views on the issue of the introduction of railways in India are well known. In 1853, in a series of articles for the *New York Tribune*, Marx observed,

> I know that the English millocracy intend to endow India with railways with the exclusive view of extracting at diminished expenses the Cotton and other raw materials for their manufactures. But when you have once introduced machinery into the locomotion of a country, which possesses iron and coals, you are unable to withhold it from its fabrication The railway system will therefore become, in India, truly the forerunner of modern industry.89

Although Marx shared the prevalent views of his time, towards the end of his life, after reflecting on the actual consequences of the introduction of the railways and British rule in India, his opinion was modified drastically. Just two

years before his death he observed,

> In India serious complications, if not a general outbreak, are in store for the British government. What the English take from them annually in the form of rent, dividends for *railways useless to the Hindus* what they take from them without any equivalent and quite apart from what they appropriate to themselves annually within India amounts to more than the total sum of income of the 60 millions of agricultural and industrial labourers of India. This is a bleeding process with a vengeance! 90

In general, the prevailing view in that period was that the introduction of railways and other technologies of communication like the telegraph and a uniform postal system would "regenerate" the Indian people from their state of "passivity" and "indolence," while rendering them more governable and more responsive to imperial imperatives. Harriet Martineau, writing in 1857, captured the essence of this view, even while reflecting on some of the possible risks to the Empire, when she observed:

> The great fundamental condition of goodness of every sortpatient slownessseems to the Hindoo to be overthrown by our inventions. Immutability, patience, indolence, stagnation have been the venerable things which the Hindoos hated the Mussulmans for invading with their superior energy; and now what is Mussulman energy in comparison with ours, judged by our methods of steaming by sea and land, and flashing our thoughts over 1,000 miles a second.91

Martineau's apprehensions were not unjustified, as she wrote these lines on the eve of the rebellion of 1857. Barely a few months after Dalhousie left India, secure in the belief that the railways, the telegraph, the postal system, and English education had secured the compliance of Indian subjects and strengthened British rule, the fierce and widespread rebellion of 1857 put an end, at least temporarily, to such hopes. Although the varied causes of the rebellion have been analyzed in detail by a number of historians, as Michael Adas has pointed out, most scholars agree that the uprising was partly in response to the wide-ranging social changes that Dalhousie's technological innovations had set in motion.92In the end, however, the ruthless suppression of the rebellion may not have been possible without the same technological innovations, especially the telegraph links between the various cities.

As Marx realized toward the end of his life, the railway system did not prove to be the harbinger of "modernization," and it did not, as many colonial administrators had expected, lead to the destruction of the caste system. In fact, railway passengers refused to violate caste rules against commonality, and

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other dietary restrictions, and as a consequence, the early passenger trains had to stop for half an hour for lunch and dinner which enabled the travelers to prepare their own food by the side of the tracks. 93As Daniel Headrick has pointed out, although passenger trains did bring together members of various castes in the same compartments, they also contributed to the evolution of a new caste system, "Hindus and Muslims in third class and in the lowest jobs, Europeans in first class and in executive positions, and Anglo-Indians in the middle."94

Nor did the railways bring about any positive transformation in the Indian economy. The economic consequences of the introduction of the railways in India can be compared with Japan.95In Japan the railway system was introduced in 1872, with the help of a number of hired European technicians, including a British engineer. The Japanese regarded these technical experts as "teachers" rather than merely railroad builders, and as early as 1877, the line between Kyoto and Otsu was built without any foreign help. By 1885, Japan had dispensed with all foreign advisers. Although the same technology was introduced in both India and Japan at roughly the same time, there was a world of a difference in the prevailing social structure of these societies. Comparing the social and economic consequences of the introduction of railways in Japan and India, Daniel Thorner has observed,

> The foreign orientation of India's economic life and the wasteful uses of her limited resources stand in sharp contrast to the domestic orientation of Japan's economy and the careful husbanding of the limited capital available to the Japanese. [T]he difference in railway policy simply illustrates the difference in the direction and emphasis between a country running its own affairs and a dependency whose affairs were being managed by an external power.96

In the case of India, the railways were transporting raw material like cotton out of India to the mills of Lancashire, and

transporting the imported finished cloth as well as other articles back to the Indian markets. Although there were various other factors involved, given the differences between the social structures of Japan and India, the further evolution of these societies took quite different routes.

Crown Rule and Science and Technology Policy after 1857

The rebellion of 1857, which came as a surprise to most colonial administrators, brought an end to the Company's rule, and in 1858, India was placed under direct Crown rule. In a way, the rebellion of 1857 had vindicated the Orientalists' arguments about the gradual introduction of science, technology and English education. After the Government of India was controlled directly

by the Crown, a number of changes followed, including the reorganization of the armed forces, more pronounced social distance between Indians and the English, and the deployment of a combination of concession and coercion for the maintenance of imperial power and authority. It was a period that led to further centralization and government control of existing scientific and technological institutions. Post-1857 India represented an era of "constructive imperialism," which implied, in the words of one colonial administrator, that the empire would henceforth be maintained "in part by concessions, in part by force, and in part by the constant intervention of new scientific forces." 97The perceived role of science, especially education in science, was articulated by S. Goodfellow, an engineer who argued:

> In prosecuting the study and in contemplating the structure of the universe, and in the consequences resulting from them, they can scarcely fail of relieving themselves from a load of prejudices and superstition; they will thus gradually, in proportion as their knowledge is spread, become better men and better subjects, and less likely ever to be made the tools of any ambitious man or fanatic.98

Although in the initial stages of the introduction of railways a number of private companies had been awarded contracts under guaranteed loans by the government, after 1858 the system was reconstituted as a state enterprise under the Public Works Department. Similarly, due to financial strain on the Company, some private companies had initially been allowed to undertake the irrigation projects. However, in 1864 all such contracts were terminated and all irrigation projects became government undertakings. In yet another "invention of tradition," the colonial state represented itself as the "landlord" vis-à-vis the cultivators, and the dispatch of 1864 from Charles Wood, the secretary of state for India stated

> [H]owever desirable it may be for the Government to avail itself of the agency of companies in carrying on irrigation and other similar works of public utility, the close connexion between the interests of the Government which receives and those of the *Ryots* who pay, the rent of the land, and the intimate relations which are thereby created between them, render it very undesirable that works of irrigation and the arrangements connected with the return from them, by those interests and relations may be so materially affected, should be in other hands than those of the government.99

With the onset of Crown rule, faith in science and technology as an integral component of government and administration was further reflected in state policies. The engineers associated with the Public Works Department who were appropriately designated as "scientific soldiers," worked in various fields of applied science and technology, such as forestry research, coal exploration and mining, manufacturing of iron rails, locomotive design, etc.100

Recurring Famines, Commissions of Inquiry, and Scientific Research

As in the early phases of colonial rule, the greatest challenge faced by the new government under Crown control was the recurring famines. The government attempted to deal with the recurring famines on a more organized footing through the conscious application of science and technology. 101One of the first steps was to appoint a Famine Commission to investigate the causes and possible solutions to the problem.

The commission, headed by Richard Strachey, examined the system of administration, land tenures, communications,

irrigation, and agricultural improvement. The *Report of the Famine Commission of 1880* emphasized the duty of the administration to take measures to prevent the famines as "the Goverment stands in the place of the landlord to the agriculturalists."102The report specifically recommended the "diffusion and application of a scientific knowledge of agriculture in India, and the provision of a class of officers in the public service who shall possess such knowledge and be in a position to apply it effectually."103To accomplish this objective, the creation of agricultural departments in each province was also recommended. The report also advocated a more systematic collection of meteorological data in order to predict famines and extensive research in the area of solar physics, as a number of scientists were claiming to have detected a correlation between sunspot activity and the frequency and amount of rainfall. For example, Norman Lockyer, a geologist working in India had published a paper titled "The Cycle of Sunspots and of Rainfall in Southern India," and the commission reprinted it in its report and recommended further research on this issue.104Another area of scientific research identified by the commission related to arriving at a "scientific" answer to the question: "How much food does a human need in order to live and work?"105The application of scientific and instrumental rationality for addressing and resolving problems caused by social factors such as specific colonial policies had a strong appeal for the administrator.

Most of the recommendations relating to the application of science and technology to agriculture were implemented by the government, and the *Report of the Famine Commission* stimulated research in a wide range of scientific fields. Agricultural departments were created at the center and in the provinces and existing technical departments were supplemented by scientists specializing in astronomy, telegraphy (for improved communications during famines), chemistry, agriculture, and forestry. Meteorological research and astronomy, which facilitated the study of sunspot activity, also received further financial support. Although a number of agricultural societies had been in existence for some time, and research designed for agricultural improvement had been conducted sporadically by individuals associated with the Company,

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the colonial state under Crown control attempted to embark on scientific research on a more organized footing. 106On the whole, the government preferred to provide scientific and technical solutions, administered by an army of "scientific soldiers," even when it was quite clear to them that social and structural factors constituted the major cause of the problem.

In responding to the Famine Commission report, the government acted on the recommendations pertaining to the development of agriculture and ignored other specific and more significant suggestions. For example, the *Report of the Famine Commission* had specifically emphasized that,

> A main cause of the disastrous consequences of Indian famines, and one of the greatest difficulties in the way of providing relief in an effectual shape is to be found in the fact that the great mass of the people directly depend on agriculture, and that there is no other industry from which any considerable part of the population derives its support. The failure of the usual rains thus deprives the labouring class, as a whole, not only of the ordinary supplies of food obtainable at prices within their reach, but also of the sole employment by which they can earn the means of procuring it. *The complete remedy for this condition of things will be found only in the development of industries other than agriculture and independent of the fluctuations of the seasons*.107

However, these recommendations were not implemented in a society that had witnessed a progressive "deindustrialization" and was now conceived primarily as a market for British industrial goods and a source of revenue from agriculture. That the colonial administrators were aware of the social origins of the recurring famines is evident from the report of an agricultural chemist, John Augustus Voelcker, who was appointed by the government to investigate avenues for further agricultural improvement and to evaluate the progress of the implementation of the *Report of the Famine Commission of 1880*. In his *Report on the Improvement of Indian Agriculture* (1893), Voelcker declared: "I believe that in many parts [of India] there is little or nothing that can be improved, and that what was necessary was better facilities."108As Dionne and Macleod point out, although the term "facilities" appears to be vague, in the context of his report, it refers to social and economic conditions.109However, the government ignored this aspect of Voelcker's report and stressed the continuing need for purely scientific and technical solutions to the problem. Despite the scientific research initiated as a result of the Famine Commission report, the famines continued unabated and so did the proliferation of new commissions and inquiries. From all these commissions, the government was receiving similar advice until 1920 when the Royal Commission on Agriculture expressly instructed its investigators "to exclude from the scope of recommendation of the Royal Commission all matters which are of special interest to the Local Governments

and might cause embarrassment, arouse apprehension or form subjects of public controversy, e.g., systems of land

ownership and tenancy assessment, land revenue, and irrigation charges. 110Any policy that might affect the revenues from agriculture or prove to be politically risky, was to be avoided. By the late nineteenth century, there was political pressure from the newly formed Indian National Congress, which was calling on the government to justify its rule, and in this context, the establishment of commissions and institutions for agricultural research into the causes of famines were not without their symbolic value.

"The Great Experiment" and "the March of Science": Lord George Curzon and the Board of Scientific Advice

The new viceroy, George Curzon, arrived in India in 1898 in the aftermath of yet another spell of devastating famines of 18971898. Curzon was determined to improve on the efforts of his predecessors to apply scientific research and technological innovation to the problem of famine. At a farewell dinner at the Royal Society's Club, Curzon had expressed his appreciation at "being entertained by a number of gentlemen who are interested in many branches of scientific inquiry," and had impressed upon his audience that "it is in Asia, and in India that the great experiment is being made. [T]he march of science and the improvements in steam communications are everyday bringing India nearer ourselves.111The perception that science, technology, and education were significant components of the colonial administration was not lost on Curzon, who underscored his conviction that "Scientific Research [is] the apex of educational advancement,"112and emphasized that "in proportion as we teach the masses, so we shall make their lot happier, and in proportion as they are happier, so they will become more useful members of the body politic."113

Despite all earlier attempts to prevent famine through the intervention of scientific research and knowledge, a recurring wave of famine struck India at the turn of the century. The famines of 18971898 were followed by yet another spell in 1900 that eliminated virtually all livestock and left over six million people destitute.114Although a number of famine relief measures were undertaken, including the implementation of Famine Relief Codes, Curzon was more determined than his predecessors to apply scientific research in a much more organized fashion for the prevention of famine as well as for confronting other problems faced by the colonial administration. Under the Curzon administration, agricultural research was the focus of special attention. Additional experts were appointed, and a large number of experimental farms and agricultural colleges were established. A major milestone in the stimulation of agricultural research on a scientific basis was the establishment of the

Imperial Agricultural Research Institute at Pusa in Bengal. A number of measures were undertaken to rectify the disadvantages that the scientists working for the government faced vis-à-vis other civil servants. These disadvantages included low prospects for promotion and lack of graded increases in salary. As J. N. Lockyer, an influential scientist and president of the British Association pointed out in his report on the working conditions of scientists in India, "men of science are after all men, and are no more likely than others to work heartily without any hope of increased pay or promotion and increased emoluments granted to those in other branches of the state service of their own waterlogged condition. 115

The most significant step undertaken by Curzon was the creation of a Board of Scientific Advice in 1902 to coordinate all scientific research in India. However, prior to the creation of the BSA, Curzon's predecessor, Lord Elgin, had been instrumental in establishing another scientific body, the Indian Government Advisory committee (IAC) which was expected to obtain advice on matters pertaining to scientific research in India from the Royal Society.116Prior to the arrival of Curzon in India, the IAC had been inactive, and the Royal Society had never been consulted nor called upon to offer any scientific or technical advice. Curzon, determined to tackle colonial problems through the application of scientific research, apologized to the Royal Society for the government's neglect of the IAC and expressed the administration's wish to "avail ourselves of the advice and assistance which the Royal Society have so generously placed at our disposal."117At the same time Curzon also announced the creation of a new body, the Board of Scientific Advice, "by which the whole scientific work carried out under the Government of India should be supervised by a Board of Experts to whom report should be made by various scientific branches."118The raison d'être of the BSA was the need to

have a central authority that would coordinate and facilitate the application of science to problems relating to the economy and agriculture. Research leading to "practical" applications was emphasized, and "pure" science was to be discouraged. According to Curzon's reformulation of the Board's agenda, "In view of the fact that the Indian government owns the largest landed estate in the world, that the prosperity of the country is at present mainly dependent upon agriculture, that its economic and industrial resources have been very imperfectly explored, and that funds available for scientific research are limited, the importance of practical research is preeminent."119Curzon's concerns and views were represented in the resolutions passed by the Government of India in 19021903, which observed that "undue prominence had been given in the past to pure science, to the neglect of its economic application."120

The Board of Scientific Advice met periodically to discuss, evaluate, and coordinate scientific research in India and published an annual report for this purpose. The Board's annual reports were communicated through the secretary of state for India to the Royal Society, which, through consultation with

the Indian Government Advisory Committee, would further evaluate and advise the Government of India on scientific issues. The board, which included the heads of all scientific services in India, bore a striking resemblance to a "Scientific Advisory Council" proposed for Britain three decades earlier by Alexander Strange and Norman Lockyer. In 1870, Alexander Strange had urged the creation of a new "Council of Science" to advise the British government on all scientific questions so as to "substitute concentration for scattered effort, system for chance, organization for disorder." 121While the proposed council for centralizing scientific research had never been established in Britain, the creation of the board in India provided an opportunity for scientists and statesmen in Britain to observe, as Roy Macleod puts it, a "controlled experiment in the co-ordination of scientific policy in the vast 'social laboratory' of Imperial India.122

The creation of the Board of Scientific Advice and its expected benefits were described by Curzon as the "greatest and noblest that anywhere devolves upon the British race."123For the first time in British history, the efficacy of a state-sponsored organization possessing central authority to direct scientific research was being tested and the scientific journal *Nature* as well as other newspapers provided extensive coverage of the "experiment." After observing the functioning of the Board of Scientific Advice in India, Sir Norman Lockyer, an influential scientist and editor of *Nature*, felt that the institutional experiment provided significant lessons for the organization of science in Britain. Lockyer observed: "The importance of such a Board is many times greater at home with so many external interests to look afterproblems common to peace and war, problems requiring the help of the economic as well as the physical sciences."124In Britain it was a period of the "national efficiency" movement led by the scientist J. B. S. Haldane, Balfour, and the Webbs. The movement, which later came to be known as the "Haldane principle," advocated a central coordination of scientific and economic policy. As such, the functioning of the board in India aroused considerable interest among British scientists and statesmen.

Over a period of time, there developed a number of differences between the Royal Society and the board, which emerged primarily due to a conflict of interpretation over "fundamental" versus "applied" science and over whether Indian scientists were capable of engaging in "pure" research. These problems were compounded by the amount of time it would take the Royal Society to evaluate proposals by the board. Despite these problems, the activities of the board did in fact provide a model for the creation of the British Science Guild in 1905. As Roy Macleod has pointed out, Norman Lockyer's approval of the fact that, in India, "research is directed to practical problems that require early solution, and is not wasted on inquiries which are only of importance from the theoretical standpoint," provided the guiding theme of the British Science Guild throughout the period 19051929.125And in 1915, the Advisory Council

on Scientific and Industrial Research was established in England, on lines very similar to the Board in India, 126Over a period of time, the principle of central coordination that the board had "helped to pioneer had become part of the received wisdom of government, both in England and in India."127As such, the BSA occupies a unique place in the history of British scientific administration, and, in addition to providing the inspiration for the new Advisory Council for Industrial and Scientific Research, the board also served as the model for a number of other scientific organizations in Britain. The final roster of organizations inspired by the experience of the board in India includes: the committee of Civil Research

(1925); the Economic Advisory Council (1930); the Scientific Advisory committee (19401945); the Council for Scientific Policy (19661973) and the Central Advisory committee on Science and Technology (19671970).128The responsibilities of the Board of Scientific Advice in India included coordinating research in areas like meteorology, terrestrial magnetism, agriculture, soils and manure, forestry products and veterinary sciences.

By the 1920s significant political developments in India, like the growth of the *Swadeshi* movement, demands for "local government," and devolution of power, combined with the growth of university-based research and of foundations in India had led to uncertainty about the future of the board. In 1923, the board was dissolved as part of a "temporary economy measure" by the treasury, and it was eventually superseded by other scientific organizations like the Indian Science Congress (1924), the National Institute of Science (1935), and the Indian Academy of Science (1934). Eventually the Council for Scientific and Industrial Research (CSIR), established in 1934, succeeded the board and sponsored combined research in the life sciences, physical sciences, and applied science.129Like William Jones's Asiatic Society of Bengal, which spawned a number of scientific organizations in late eighteenth- and mid-nineteenth-century India, a few decades later, the board played a similar role in providing the impetus for a number of scientific institutions both in India and England.

The attempted application of science and technology to alleviate the famines did not bear much fruit, and the most devastating of Bengal famines were yet to occur in the early 1940s. Nevertheless, at the end of his tenure, Curzon believed his "great experiment" was not fully over and he sought and was granted an extension as the viceroy of India. When a number of Indians made representations to him, urging him to take some action regarding the recurring famines, Curzon pointed to a list of scientific programs initiated by the administration during his tenure: "We have created an Inspector General of Agriculture. [W]e have constituted a Board of Scientific Advice. [E]xtended irrigation, improved education crop experiments, scientific research, and a careful overhauling of the machinery with which we meet drought when it comes."130Although he exhibited great faith in the efficacy of scientific and technical solutions to the problem of famine resulting primarily

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from colonial policies, Curzon, when pressed further on the issue of famine by Rai Sri Ram Bahadur, responded, "to ask any Goverment to prevent the occurrence of famine in a country, the meteorological conditions of which are what they are here, and the population of which is growing at its present rate, is to ask us to wrest the keys of the universe from the hands of the almighty." 131And for the benefit of critics in Britain who were by then well aware of the recurring famines and the consequent human suffering, Curzon provided another list of the benefits colonial rule had conferred in India and exclaimed that he was,

> lost in amazement at those critics who fail to see these things, who protest to us that our rule in India is ruining the country and crushing the people; I am still more amazed when I reflect that that class of critic is, as a rule to be found among a small set of my own countrymen. It seems to me so perverseI had almost said to wicked. The cant of self-praise is a disagreeable thing, but the cant of self-depreciation seems to be even more nauseating. Of the two types of Pharisee, the man who takes pride in his virtues is often less offensive than the man who revels in imaginary sins.132

In response to growing criticisms of colonial rule within Britain, Curzon reminded his audience at a gathering in London that "we all live in a severely practical age," and he attempted to convey "some idea of the part that India has recently played in the Imperial burden ," by providing several "concrete illustrations":

> If you want to save your Colony of Natal from being overrun by a formidable enemy, you ask India for help and she gives it; if you want to rescue the white men's legations from massacre at Peking, and the need is urgent, you request the Government of India to dispatch an expedition and they dispatch it; if you are fighting the Mad Mullah in Somaliland, you soon discover that Indian troops and Indian generals are best qualified for the task. It is with Indian coolie labour that you exploit the plantations equally of Demerara and Natal; with Indian trained officers that you irrigate Egypt and dam the Nile; with Indian forest officers that you tap the resources of Central Africa and Siam; with Indian surveyors that you explore all the hidden places of the earth.133

Finally, in yet another response to repeated harsh criticisms by fellow countrymen, Curzon reiterated the compulsions of living in a "severely practical age," and employed vivid imagery from agriculture to redefine the nature of the "imperial

burden":

> [t]he reason is not for the honour and glory of the thing, still less for the selfish advantage of England or Englishmen. We must remain in India, because if we were to withdraw the whole system of Indian life and politics would fall to pieces like a pack of cards. We are absolutely necessary to India. I cannot myself conceive of a time as remotely possible in which

> it would be either practicable or desirable that we should take our hand from the Indian plough. Let India remain our India, just as much as Shakespeare is our Shakespearethat is to say, as a part of the inalienable heritage of Englishmen and the lasting glory of the British race. 134

Although the problem of famines was not solved by the creation of the Board of Scientific Advice, and the colonial adminstrators never expected that it would be, the institutional experiment in state sponsored scientific research influenced the further evolution and practice of science policy both in India and Britain. Despite a lack of results from the social experiment, the governments of both India and Britain continued to place great faith in the efficacy of scientific and technical solutions to essentially social problems. In the case of India, a number of the problems, which were sought to be resolved by the intervention of scientific solutions, administered by "scientific soldiers," or, later, the Board of Scientific Advice, were in fact intimately connected to the structures of colonialism and derived from specific colonial policies. For a society that was "deindustrialized" partly as a consequence of colonial rule, there was more than a ring of truth in the scientist Sir Albert Howard's comment that "agricuture is, and for many years yet to come must remain, India's greatest industry."135

Reindustrializing a Deindustralized Society: The War and the Indian Industrial Commission, 19161918

Although all previous recommendations by the plethora of committees and royal commissions urging the government to stimulate industries had been quite deliberately ignored by the administration, the First World War brought with it awareness of new problems and issues. The war showed the necessity of producing munitions for the allies and forced the administrators to confront what the Famine Commissions had already drawn attention tothe realization that the overwhelming prominence accorded to the agricultural and geophysical sciences, had entailed the relative neglect of the application of science to industry, particularly engineering and chemistry. Despite all the state-sponsored scientific activity in colonial India, no attention had been paid to industries in India. Most of the state-sponsored scientific and technological activity had been geared toward the agricultural sector, and toward the engineering colleges and technical institutes established for the training of engineers to undertake the construction of irrigation systems. The main aim of such initiatives was to increase agricultural productivity and not the development of industries. While there were obvious structural factors that influenced such policies, theoretical support was provided by the Ricardian dictum of the

international division of labor according to comparative advantages. 136The colonies were to specialize in agriculture while pure science, technology, and industry were to be the preserve of Britain.

Industrial development had been almost completely neglected, and the war and the attendant need to produce munitions and war materiel brought about the realization that India was "not only ill-provided with the necessary machinery, but without the technically trained personnel required for industrial expansion."137Despite some of the first experiments in governmental support for the science and technology, Lord Montagu of Beaulieu, while addressing an audience in 1916 in London, admitted that "very little has been done in respect to an economic development on scientific lines."138

The Indian Industrial Commission, constituted in 1916, submitted its report, which concurred with the views expressed by Lord Montagu, in 1919. While highlighting the "unequal development of our industrial system," the report of the commission concluded that,

> Money has been invested in commerce rather than industries, and only those industries have been taken up which appeared to offer safe and easy profits. India produces nearly all the raw materials necessary for the requirements

> of a modern community; but it is unable to manufacture many of the articles and materials essential alike in times of peace and war. Her great textile industries are dependent upon supplies of imported machinery and would have to shut down if command of the seas were lost. It is vital, therefore, for Government to ensure the establishment in India for those industries whose absence exposes us to grave danger in the event of war. The deficiencies in her industrial system are such as to render her liable to foreign penetration in time of peace and to serious dangers in time of war.139

There was also the growing realization that the war might seriously disrupt transportation and communication links with Britain, and in view of such an eventuality, the report recommended that "in future Government must play an active part in the industrial development of the country, with the aim of making India more self-contained in respect of men and material." According to the report, the implementation of such a program would not be possible unless the government was "provided with adequate administrative equipment and forearmed with reliable scientific and technical advice."140

Confronted with the impending war, the officials of the colonial state attempted to chalk out plans for setting up industries despite shelving earlier proposals during famines. Illustrating a good example of "modernization theory" in the making, the report ascribed the causes of the industrial situation in which India found itself on the eve of the war to cultural factors ranging from "the general aversion from industrial pursuits of the educated Indian" and "hereditary predisposition accentuated by an unpractical system of education" to the explanation that the Indian "intelligentsia have yet to develop a right tradition of

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industrialism." 141In order to industrialize colonial India, state-sponsored science and technology, albeit on a different pattern than in the past, was advocated. The report recommended "a reorganization of the existing scientific services in such a way as to unite in imperial services, classified according to science subjects, all the scattered workers now engaged in the provinces on isolated tasks."142

The Indian Industrial Commission comprised ten members, including four Indians. One of the Indian members of the commission, Pandit Madan Mohan Malaviya agreed with the program of industrialization, but he also contributed a detailed "Note of Dissent" in which he took issue with some of the background assumptions of the report. He specifically disagreed with the assumption of the other members regarding the "causes which they assign for the growth of industries in England."143The report had argued that the Industrial Revolution was due primarily to the middle classes of England, who had "endowed it with a spirit of enquiry and enterprise that was gradually and increasingly directed to the attainment of industrial efficiency."144Through his "Note of Dissent," Malaviya, relying only on British sources, embarked on an erudite reconstruction of the social history of the colonization of India and the Industrial Revolution. Citing Edmund Burke and other scholars, as well as official dispatches from the East India Company and colonial administrators, Malaviya sought to

> remind my English fellow subjects how largely England is indebted for her "industrial efficiency" and prosperity to her connection with India, and how grave an economic wrong has been done to India by the policy pursued in the past, with the object that this should induce them the more to advocate and insist upon a truly liberal policy towards India in the future. I have also done this to dispel the idea that Indians are to blame for the decline of their indigenous industries, or that they suffer from any inherent want of capacity for industrial development on modern lines, and that Europeans are by nature more fitted than Asiatics for success in manufacturing pursuits.145

One particularly interesting example of the impact of colonial policies was the decline of the Indian shipping industry. After a reconstruction of the shipping industry in ancient times, Malaviya cited Governor-General Wellesley's dispatch to the Court of Directors in 1800. Wellesley wrote, "from the quantity of private tonnage now at command in the port of Calcutta, from the state of perfection which the art of ship building has already attained in Bengal, it is certain that this port will always be able to furnish tonnage, to whatever extent may be required, for conveying the port of London the trade of the private British merchants of Bengal." According to a British historian, "the arrival in the port of London of Indian produce in Indian-built ships created a sensation among the monopolists. who declared that their business was on the point of ruin." In this context, the reasons offered by the Court of Directors for ending the employment of Indian ships in the trade between England and India reveals the economic and

ideological insecurity of the Company at a time when the structures of colonial administration were still fragile. After enumerating a number of economic reasons for terminating the use of Indian ships, the Court of Directors contended:

> Besides these objections which apply to the measure generally, there is one that lies particularly against ships whose voyages commence from India, that they will usually be manned in great part with *lascars* or Indian sailors. Men of that race are not by their physical frame and constitution fitted for the navigation of cold and boisterous climates. [T]hey have not strength enough of mind or body to encounter the hardships or perils to which ships are liable in the long and various navigation between India and Europe. But this is not all. The native sailors of India are on their arrival here, led into scenes which soon divest them of their respect and awe they had entertained in India for the European character. The contemptuous reports which they disseminate on their return cannot fail to have a very unfavorable influence upon the minds of our Asiatic subjects, whose reverence for our character, which has hitherto contributed to maintain our supremacy in the East will be gradually changed and the effects of it may prove to be extremely detrimental. Considered therefore, in a physical, moral, commercial, and political view, the apparent consequences of admitting these Indian sailors largely into our navigation, form a strong additional objection to the concession of the proposed privelege to any ship manned by them. 146

As Malaviya pointed out, the allusion to the physique and mental fitness of the Indian sailors "sounds very curious at the present time, when so many *lascars* are employed by all the great lines of steamers running to the East."147In the course of a hundred years, the use of Indian ships for the Company's trade was banned, but Indian sailors continued to be employed on British commercial liners.

Through his "Note of Dissent," Malaviya questioned the British appropriation of the discourse of industrialization and sought to establish that "if during the century she [India] came to be predominantly agricultural, this was due to the special treatment to which she had been subjected and not to any want of industrial capacity and enterprise among her people."148He also sought to provide the members of the commission, a "lesson in history," as a counterpoint to the ontological assumption of precolonial India as a tabula rasa, onto which a scientific and technological culture had to be inscribed. The assumptions underlying the report were well articulated in Francis Spring's testimony to the commission. Spring, the chairman of the Port Trust at Madras, argued that "there was something lacking in the soul of the Indian people taken in the lump, viz. the intense internal desire for accuracy," a view that he supported by claiming that prior to the onset of British rule, Indian craftspeople were incapable of three dimensional drawing.149A similar argument that ignored history and restated yet another variation on a recurring theme of culturalist explanations was offered by W. S. Hamilton in his testimony before the Industrial Commission. According to Hamilton,

> There is little pride in doing work as thoroughly and as quickly as it can be done but there is everywhere patent dishonesty in not working to sample, in not devoting time that has been paid for, in saving a shameful pice by misplaced putty. The rickety chairs, the misshapen keys, the shoddy *lungis*, all find their sources in this moral defect. These moral defects make Indian labour expensive though it is low paid; but we hope to eradicate it with a suitable system of education. It can be done by instilling method, by inculcating concentrated attention, by rewarding exactitude and honesty, and punishing scamping by teaching each boy to use his will as his hand, by showing through payment or promotion that good work pays. 150

Malaviya sought to interrogate the validity of such views, but he did so not simply to reassert and nurse hurt nationalist pride. Much more was at stake. The "Report of the Indian Industrial Commission" was not intended to be a passive text onto which a number of divergent views were inscribed. It was also a charter for action, and Malaviya knew that the recommendations emanating from it could influence the future development of Indian society.

The whole point of Malaviya's critique was to establish the fact that the British experience of industrialization was the outcome of a particular socio-historical and colonial context and that it would be a mistake and perhaps impossible to replicate such a model in India.151Since Malaviya argued that colonialism had played a major role in the Industrial Revolution in Britain, he drew attention to Germany and the "Asian Germany," Japan, both of whom were not major colonial powers but had industrialized successfully, as more plausible models to be emulated by India. Britain, he argued, was hardly in a position to provide models for industrialization. He referred to the first Industrial Exhibition in London in

1851 when the industrial backwardness of Germany and France vis-à-vis England was evident. However, by the fourth exhibition in Paris, held only six years later, Germany had established an overwhelming superiority over England. Malaviya felt that Germany provided a more appropriate model as it had been industrialized without the benefit of colonialism. He cited a report from an English commission of inquiry set up to investigate how England had lost to Germany in "the battle for intelligence," which had concluded that "the education of Germany is the result of national organization which compels every peasant to send his children to school, and afterwards affords the opportunity of acquiring such technical skill as may be useful in the department of industry to which they are destined."152Malaviya made his point about the irrelevance of the British model in his cross-examination of the director of public instruction of Bengal.

> Malaviya: Is it a fact that England had been much more backward in the matter of technical instruction than Germany?
>
> Hornell: Very much so. I do not think people out here realized that.

> Malaviya: And it is not much good asking us to look for a model to England for providing systematic instruction for our youth. 153

Malaviya's emphasis on Germany and Japan as suitable models had even resulted in the commission dispatching an economist to Japan to investigate how she "had developed a structure of industrial and commercial enterprise from a past which knew nothing of Western economic conditions."154In the end, however, Malaviya's proposals, although they were included as an appendix to the Report, were never seriously considered for adoption.

Despite the detailed investigations undertaken by the Indian Industrial Commission and the proliferation of endless volumes of reports, the colonial administration did not implement any of the recommendations for industrialization, and, as in the past, it emphasized research and development in the agricultural sector. With the First World War over, there were no incentives for implementing any of the recommendations of the Industrial Commission. As the Indian scientist Meghnad Saha remarked later, "from 1924, due to some mysterious reason, the Goverment of India dropped all ideas of developing the natural resources of India and concentrated purely on agricultural research and agricultural industries. What high agency was responsible for this policy was not known, but India was henceforth condemned to grow potato and paddy."155Before discussing the final debates among scientists over the significance of science and technology in Indian society, the section below examines the complexities of the Indian response to the introduction of modern science and technology.

The Indian Response to Modern Science and Technology

In an earlier section, the response of the emergent urban elite or the *bhadralok*, as represented by Raja Ram Mohun Roy has already been discussed. The members of this stratum were the direct beneficiaries of the Permanent Settlement, which had resulted in the gradual elimination of the older aristocracy. Having acquired an economic position and status in the traditional society, members of this stratum sought to legitimize and consolidate their position in the emerging colonial society. In this context, their yearning for Western education and science, while not inevitable, was not surprising. Even for those Indians in Bengal who were not part of the *bhadralok* community, education in Western science and English was perceived as the main avenue for achieving that status. As the Simon Commission report observed, "the school is one gate to the society of the *Bhadralok*."156Raja Rammohun Roy's appeal to Lord Amherst against the establishment of the proposed Sanskrit college, which he claimed, "can only be expected to load the minds of youth with grammatical niceties and metaphysical distinctions of little or no practicable use to the

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possessors or society," articulated the views of this class. Well versed in the Hindu and Muslim scriptures and influenced by Unitarian ideas, Roy's appeal to Amherst constituted a larger theistic project of reinterpreting *Vedanta* in the "light of modern science and modern progress." 157

If Roy represented the aspirations of a particular stratum of Hindus in Bengal, his counterpart was the educationist and scholar Sir Syed Ahmad Khan who sought to represent the views of the Muslims. While reflecting on the social changes wrought by colonial rule in Bengal, Sir Syed, as well as most colonial administrators, had noticed that Muslims were noticeably under-represented in English schools and in the colonial administration. Predictably enough, early colonial administrators had attributed the perceived lack of interest of the Muslims in English education and science to cultural factors or hostility towards the British as they had wrested control of Bengal from the erstwhile Muslim rulers. However, by the late nineteenth century, a senior colonial administrator like W. W. Hunter had explicitly argued that previous colonial policy, especially the Permanent Settlement, was responsible for the elimination of the Muslim aristocracy and that the administration had favored the Hindu elites. That the Muslims were generally hostile to British rule and alienated from English education was evident in the early period of colonial rule, but W. W. Hunter had rejected purely culturalist explanations. In a report titled Our Indian Musalmans: Are They Bound in Conscience to Rebel Against the Queen?, Hunter had argued that "the Mohammadans have now sunk so low that, even when qualified for Government employment, they are studiously kept out of it by Government notification."158

Sir Syed's educational project in the mid-nineteenth century can be located in the realization that while the Hindu middle classes and elites in Bengal, Madras, and Bombay presidencies seemed to be thriving under colonial rule, such was not generally the case for Muslims. To explain why Muslims in general had kept aloof from Western education, Sir Syed had invoked a combination of cultural and structural factors that included "social customs," "religious beliefs," "political traditions" and "poverty."159It was the aim of enabling the Muslim community to participate more actively in colonial society, just as Ram Mohun Roy had done so a few decades earlier, that explains Sir Syed's modernist response to science, technology, and English education. Like Roy, Sir Syed was well versed in the *Quran* and other Muslim religious scriptures, and he sought to interpret Islam in "the light of reason" by arguing that "any religion which is true or claims to be true cannot contain such elements in it as are contrary to nature and offend human reason."160Sir Syed believed that in order to attain social mobility in the colonial setting, a Muslim needed to have "philosophy in his right hand and natural science in the left."161Echoing Ram Mohun Roy's views, Sir Syed argued,

> Up to the present time the indigenous education of the country has been (like that of Europe at no very distant period) confined to the study of language

> and metaphysics, which though it undoubtedly serves to increase the mental acuteness of the learner, gives rise to none of those practical results which have been the fruits of the study of positive science amongst European nations. 162

The Aligarh Scientific Society was established by Sir Syed in 1864, with the expressly stated goal of "causing the blessed morning of civilization to dawn on the night of ignorance and darkness which for ages has retarded the advance of this country."163The resonance of the views of Charles Grant and James Mill is evident in the program of the Aligarh Scientific Society. In fact, one of the books that the Society translated into Urdu was James Mill's *Elements of Political Economy*.

Sir Syed's Aligarh Scientific Society attempted to introduce science and technology to the Indian population by means of translating English scientific books into the vernacular through the actual demonstration of the "power" of the new technology. Echoing the views of Grant and Mill, but obviously due to quite different motivations, Sir Syed believed that Indian farmers "are insensible to the evils arising from improper crop cultivation, from bad seasons and from pernicious customs of raising crop after crop. They know nothing of the lately invented processes of Europe for improving the land, nor of tilling apparatus and machines now in use there which have greatly contributed to lighten the European farmer. Let Indians follow her example, and avail herself of the many aids to those improvements which have been invented."164The society also operated an experimental farm at Aligarh, procured a "V" pump for demonstration to the public and even imported a number of vegetables and nine varieties of wheat from England for cultivation at the farm.165

The Aligarh Scientific Society and its goals were emulated and replicated in a number of places. For example, the Bihar Scientific Society was founded in 1868 with the express intention of translating English scientific works into Urdu to improve "the moral, intellectual and social condition of the people."166Similarly, a number of teachers associated with the Delhi College, including Master Ram Chandra, played active roles in teaching and translating many Western

scientific books and treatises into Urdu in the mid-nineteenth century. These efforts at popularizing modern Western science through the medium of the vernacular were met with outright hostility by the Muslim clerics. Sir Syed was labeled a "Hindustani Natury," because, as one of the clerics explained, "Ahmad Khan in order to gain benefits from the British and to destroy the Muslims became an agnostic. By playing the role of an agnostic and natury he wanted to prove that nothing existed in the world except nature and natural intellect."167Sir Syed's assertion that he was not in fact hostile to religion and had complete mastery over the religious texts, evoked the sarcastic response that he was as "skilled in religion as a monkey who has fallen into a pan of indigo considers himself to be a peacock."168In the long run, Sir Syed's project

led to the establishment of the Mohammedan Anglo-Oriental College in 1877, later to become the Aligarh Muslim University, where instruction in Western science was offered.

In addition to the response of Ram Mohun Roy and Sir Syed to modern Western science and technology, there were others like Radhakant Deb and Nundcomar Mukherjee who attempted to "unearth dubious equivalents for every modern scientific theory, from the canonical Indian literature," 169a tradition that continues to this day in contemporary India. In sum, the above account represents the response of the nonscientists to Western science, and it clearly indicates that in the context of changing structural conditions under colonial rule, the elite sections of Indian society were active agents in the transmission and spread of the new scientific worldview. It was hardly a case of modern science and technology being imposed by the British on an unsuspecting Indian population, as has been argued by some.170In the discussion below, the response of the some Indian scientists to the British policy on science and technology is examined.

The Response of Indian Scientists: Mahendar Lal Sircar and the Indian Association for the Cultivation of Science

By the late nineteenth century, many Indians responded enthusiastically to the introduction of Western science and technology, but they were discouraged by the heavy emphasis on applied technical education and the visible neglect of theoretical scientific research and teaching. Such a policy was reinforced by the prevailing view in the colonial administration and in England that Indians were incapable of engaging in fundamental scientific research. As a consequence, when scientific teaching was introduced in higher education at Presidency College, Calcutta, qualified Indians were denied positions, and faculty members were recruited from England.

The discrimination against Indian scientists can be illustrated by examining the experience of two outstanding Indian scientists of the time. J. C. Bose had trained at Cambridge under Rayleigh and Francis Darwin, and his work had evoked enthusiastic response from leading English physicists like Kelvin and William Ramsay. Kelvin, for example, had written that he was "literally filled with wonder and admiration" for Bose's work.171When Bose returned to India in 1885, the principal of Presidency College objected strongly to his appointment as a junior professor of physics. He was eventually allowed to take up the position only if he agreed to receive two-thirds of the regular salary. Bose accepted the position but registered his protest at the treatment meted out to him by never touching his monthly check.172P. C. Ray, another

outstanding scientist, obtained his D.Sc. in chemistry from Edinburgh and returned to India in 1888, hoping for an appointment in the Bengal Educational Service, but had to wait for over a year before being appointed to the position of a temporary assistant professor. Ray protested, contending that "if a British chemist of my qualifications were present, he would have been appointed immediately by the Secretary of State to the Imperial Service." 173These were just two outstanding Indian scientists, and part of the anglicized intelligentsia, who were denied positions and therefore opportunities for research due to pervasive racism in that period.174Patrick Geddes, a British administrator and the pioneer of sociology in India, aptly summarized the prevailing conditions in the following words:

> There was a strong doubt, not to say prejudice against the capacity of an Indian to take any important position in science. [I]t was assumed that India had no aptitude for the exact methods of science. For science therefore India must look to the West for teachers. This view was accepted and so strongly maintained in the education department that when Bose was appointed officiating Professor of Physics in Presidency College, its Principal

> objected on the above grounds.175

It was under these conditions that the Indian Association for the Cultivation of Science (IACS) was established due to the initiative of Mahendar Lal Sircar. Although the association was formally established in 1876, i.e., about a decade before J. C. Bose and P. C. Ray experienced problems in gaining employment as scientists, the situation had been far worse earlier.

Mahendar Lal Sircar's appeal for the establishment of an institution that would combine teaching and scientific research and would be "entirely under native management and control,"176attracted funds from a number of Indian patrons. At the first meeting of the association, Sircar criticized the exclusive focus of the colonial government on technical education and observed "with deep regret that our government has hitherto afforded no opportunity nor afforded any encouragement to the pursuit of science by natives of this country."177He bemoaned the fact that the colonial "government has to bring out men from England whenever any necessity arises for carrying on investigations in any subject and even for professorships in its educational institutions," and he hoped that in the face of discriminations against Indian scientists, the IACS would demonstrate that "despite the inherited submission to a foreign yoke we have inherited a mind not inferior in its endowments to the mind of any nation on earth."178Sircar emphasized a combination of teaching and research since "nothing enables a man to learn as well and as thoroughly as the necessity to teach."179

However, not all Indians shared Sircar's ideas. His plan for founding an institution was opposed by members of the Indian League who believed that Indians were not yet capable of undertaking basic scientific research and should continue to work on purely technical problems. The chairman of the

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Indian League, K. M. Banerjee disagreed with the IACS's goal of attaining "personal independence with the acquisition of knowledge and the attainment of university degrees and Honours." He argued that "no one could hail the day with greater favor than himself it that scheme could give rise to Indian Galileos, Indian Newtons, Indian Herschels [but] existing circumstances compel him and his friends to think of utilizing the discoveries already made before aspiring after such discoveries." 180The objections of the Indian League were rebutted by Rev. Eugene Lafont, a science teacher associated with the IACS. Lafont defended Sircar's plan by arguing that,

> The Scientific Association was not intended to produce Newtons, Galileos and Herschels, though even that was not impossible but its primary object was very different [The Indian League] wanted to transform the Hindus into a number of mechanics requiring for ever European supervision whereas Dr. Sircar's object was to emancipate in the long run his countrymen from this humiliating bondage.181

To the charge of the Indian League that basic scientific research was irrelevant, Sircar responded by arguing that he did not deny the importance of technical education, but that "preliminary scientific education must precede scientific education, and before making provision to establish the former on a secure basis, it would be madness to waste energy and fritter away funds for the mere name of technical education."182

The Indian Association for the Cultivation of Science was formally established in 1876, and the scientists associated with it began offering courses in a number of fields. In the next few years, with funds from a number of Indians, including an unsolicited grant from the maharaja of Vizianagram, a laboratory equipped with instruments introduced into India for the first time was established. The IACS funded and supported basic research for a number of Indian scientists, and an entire school of Indian physicists was trained at its Cultivation of Science Laboratory. Sircar's understanding that the Indian scientists would not thrive under the colonial system of education was vindicated when C. V. Raman, one of the students of the IACS who was expected to be "the brightest ornament of the Association," became the first Asian scientist to win the Nobel Prize for theoretical physics in 1930 for the discovery of the "Raman effect." The IACS was eventually affiliated with the newly created physics and chemistry departments of Calcutta University, and Sircar's goal of combining scientific research and teaching was realized with the creation of the University College of Science in Calcutta in 1916.183The University College constituted an institutional locus for the leading Indian scientists, who were active participants in the final debates prior to independence, about the role of modern science and technology in Indian society. These debates over competing versions of science and technology were to substantially influence the direction of the evolution of Indian society.

"Weeding Out Medieval Passions" through the "Beauty and Power of Science": Meghnad Saha and the Industrialization of India

Liberal donations from a number of wealthy Indian patrons enabled the establishment of professorships in physics, chemistry, botany, and applied mathematics at University College, Calcutta. Among the Indian professors appointed was P. C. Ray who had earlier experienced tremendous difficulties in obtaining employment with the Bengal Educational Board. In the initial stages of his career, Ray was an ardent proponent of the application of scientific research for industrial development. He was not just interested in theoretical chemistry, but had, in fact, succeeded in establishing the first full-fledged chemical laboratory in Calcutta. In his efforts to demonstrate that theoretical chemistry could be harnessed to industrial growth, Ray had established a number of industrial concerns, and he would have readily endorsed Mahendar Lal Sircar's belief that "It is the chemist who must come to the rescue of threatened communities. It is through the laboratory that starvation may be eventually turned to plenty." 184However, by the late twenties, Ray had lost confidence in the program of heavy industrialization being promoted by his own students at University College. Earlier, he had dismissed Gandhi's views on heavy industrialization but had now become one of its most committed advocates. As he recounted:

> Ever since my college days in the eighties of the last century I have been a devoted student of Western Science and I have tried my best to divert science to practical application. It has been my privilege to be instrumental in introducing in Bengal at least one aspect of science [T]he great experimental chemist Liebig laid down that the industrial progress of a country was measured by the output of its sulphuric acid. And it so happens that I am intimately associated with several concernsone which manufactures soap in large quantities and another BPCW, which bids fair to be the biggest producer of India of sulphuric acid and its accessory products. When Mahatmaji [Gandhi] in 1921 first made the *Charkha* the symbol of the new movement, I myself, a staunch believer in mechanization, laughed at this relic of medievalism.185

However, it was during his involvement with a series of flood and relief operations in Bengal that Ray began to question his commitment to heavy industrialization through the application of science and found Gandhi's views more appealing. To those who were proponents of heavy industries, Ray posed the question: "At the most 2 millions earn their bread in the industrial centres of India, but what of the remaining 318 million? Will you wait till Manchesters, Liverpools, Glasgows and Dundees spring up here and transfer 70% of the rural population to India? I am afraid you will have to wait until doomsday."186While criticizing the proposal for building heavy industries by

other Indian scientists, Ray emphasized that he was not completely against all industrialization. As he put it:

> The problem of distribution is not a whit less important than the problem of production; what do we gain if millions of our countrymen starve while a few fatten on unnatural grain? I need not be understood as saying all big scale industries should be smashed. The thing cannot be disposed away so airilyI could not even if I would. But surely you will agree with me that if the same result can be brought about by means much less harmful, surely that is preferable. 187

However, the views of P. C. Ray were not acceptable to his students, particularly Meghnad Saha, who was by now the leading Indian astrophysicist and was also actively involved in the emerging politics of the Indian National Congress. The Indian National Congress had advocated a program of heavy industrialization almost immediately after its inception. This advocacy was muted only during the period when Gandhi had assumed the leadership of the party, but although his emphasis on cottage and village industries had been incorporated within the party program, those who held such views did not constitute the dominant faction. In 1935, when the Government of India Act conferred a more active role on the Congress party, the views of the faction that espoused Gandhi's ideas were audible but not very influential. The worldview of the party was articulated by Jawaharlal Nehru in 1937. Nehru asserted, "Congress represents science, and science is the spirit of the age and the dominating factor of the modern world. Even more than the present, the future belongs to science and to those who make friends with science and seek its help for the advance of

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humanity."188Following the provisions of the Government of India Act, elections were held in 1937, and Congress ministries were formed in most of the provinces. In 1938 a National Planning committee was convened with Nehru as its chairman. The Planning committee included a number of industrialists, and most importantly, the leading proponent of heavy industrialization, and P. C. Ray's student, Meghnad Saha.

In 1934, Saha, together with a group of leading Indian scientists had established the Indian Science News Association and an influential journal, *Science and Culture.*189This association of scientists which came to be known as the "Science and Culture Group," advocated the utilization of scientific knowledge for heavy industrialization. Impressed both by the results of planned industrialization in the Soviet Union and the project of the Tennessee Valley Authority, Saha and his group vigorously criticised the Gandhian program in the pages of *Science and Culture*. Saha alone published a staggering number of 2,100 articles and 4,600 notes attacking "Gandhian regressiveness." In one editorial, he argued that "we do not for a moment believe that better and happier conditions of life can be created by discarding modern scientific techniques and reverting back to the spinning wheel, the loin cloth and the bullock cart."190While admitting

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that "it is a fact that a large section of the masses have suffered terribly from the effects of industrialism as practised in India today, which amounts to the exploitation of the masses for the benefit of the few," Saha, to use Shiv Visvanathan's words, conjured a Saint-Simonian vision by arguing,

> [R]ivalry amongst nations should give way to co-operative construction and the politician should hand over his functions to an international board of trained scientific industrialists, economists and eugenists who would think in terms of the whole world and derive means by which more and more of the necessities of life can be got out of the earth. It may be a dream, but it is feasible provided the educational programme of the coming generation is thoroughly revised. A new educational scheme should be devised by a world congress of the foremost thinkers like Bergson, Einstein, Russell, Smuts, Spengler and others, with the special objective of weeding out medieval passions from the minds of coming generations and for training them to a proper grip and sufficient appreciation of the beauty and power of science. 191

As a member of the first National Planning committee set up in 1938, Saha played an influential role in setting priorities for the industrial development of the country.

However, not being totally satisfied with the pace of change between independence and 1951, Saha decided to contest the forthcoming elections for the post of a member of the Parliament as a Congress candidate. However, he was a strident critic of Gandhian views, which the new Congress government, although it had adopted quite different policies, did not want to repudiate publicly. Criticizing Gandhian views publicly was a sensitive issue, and Saha was asked to recant his earlier views on Gandhi as a precondition for receiving the party's nomination. He refused to recant "because I believe and have proved that this insistence on primitive technology shows a very retrograde and antiscientific mentality, and persons who are wedded to this mentality would bring disaster to the country when they are in power."192Ultimately Saha contested the elections as an independent candidate against the Congress nominee, and despite popular support for the Congress party, he was elected as a member of the Parliament in 1951. The leading astrophysicist of India was now a formally accredited politician. Despite the temporary friction between him and the Congress party, Saha, the group of scientists associated with *Science and Culture*, as well as other like-minded scientists were extremely influential within the administration, and were instrumental in setting the agenda for the application of science and technology with the aim of developing heavy industries.193

As evident from the above discussion, the response of Saha and other scientists to Western science and technology was not uncontested, but by working within a specific structural context and being intimately connected with political power in newly independent India, they were able to exercise an enormous amount of influence on the future science policy of the country.

There was, however, another response to Western science and technology, which was represented by the work of Srinivasa Ramanujan. The section below provides a brief account of the work of this outstanding mathematician, who

attempted to draw on certain Indian cultural resources to respond to Western mathematics.

Born in 1887, Srinivasa Aiyangar Ramanujan worked as a clerk for the Madras Port Trust. He had started university education but had given up after the first year due to financial difficulties. His major contact with formal mathematics was George S. Carr's *Synopsis of Elementary Results in Pure and Applied Mathematics*, which he had borrowed from the local Government College. Ramanujan managed to work through the mathematical problems in Carr's book, and soon moved beyond it, developing his own theorems and ideas. His employer encouraged him to communicate with the Cambridge mathematician Godfrey H. Hardy and in 1913, Ramanujan sent him a letter, claiming to have solved some problems about prime numbers that had defeated eminent mathematicians like Legendre and Gauss. Although Ramanujan did not enclose the solutions to the problems, he did send some other theorems and equations that he thought would be of interest to Hardy. Two months later, with scholarships from Madras and Cambridge Universities, Ramanujan was at Cambridge. While at Cambridge, Ramanujan startled Hardy and other mathematicians both by working out problems never solved before and by his total ignorance of any formal mathematical methods or any field except number theory.

He spent only five years at Cambridge, and by the time he left for India, following an attempted suicide after Trinity college refused to renew his fellowship, Ramanujan had managed to solve a number of the most intriguing mathematical problems. What the English mathematicians were most intrigued by and, at times, embarrassed about was the explanation Ramanujan offered regarding his methodology for arriving at solutions. A devout Hindu, Ramanujan claimed he derived most of his solutions with the help of the goddess Namgiri. He claimed that "an equation for me has no meaning unless it expresses a thought of God," and that the quantity 2n-1 stood for "the primordial God and several divinities." 194Apart from invoking God and several deities, Ramanujan was unable to provide any explanation of his "methodology" in formal mathematical terms. Regarding his "methodology," G. H. Hardy observed, "His ideas of what constituted a mathematical proof were of the most shadowy description. All his results, new or old, right or wrong, had been arrived at by a process of mingled argument, intuition, and induction, of which he was entirely unable to give a coherent account."195Hardy and his colleagues were frequently embarrassed by Ramanujan's invocation of Hindu gods and dreams as the source of the solutions. But in Hardy's words,

> his knowledge of English was insufficient to qualify for a degree. It is sufficiently marvelous that he should have even dreamt of problems such as

> these, problems which it had taken the finest mathematicians in Europe a hundred years to solve, and of which the solution is incomplete to the present day. [W]ith his memory, his patience, and his power of calculation, he combined a power of generalization, a feeling for form, and a capacity for rapid modification of his hypotheses, that were often really startling, and made him, in his field without a rival in his day 196

In any event, the Cambridge mathematicians, while intrigued by his work, refused to take Ramanujan's explanation of his methodology or his invocation of Hindu deities seriously. As Hardy put it, his work "would be greater if it were less strange."197

Hardy attempted to teach Ramanujan the fundamentals of mathematics as he thought it was "impossible to allow him to go through life supposing that all the zeros of the zeta function were real," but he soon discovered that although "in a measure I succeeded I learnt more from him than he learnt from me."198Another Cambridge mathematician who attempted to teach him the fundamentals of mathematics found the experience "like writing on a blackboard covered with excerpts from a more interesting lecture."199Although Ramanujan died at the young age of thirty-three, he was, as one of his teachers at Cambridge remarked, "a mathematician so great that his name transcends jealousies."200The results of his mathematical work, much of it jotted in his private notebooks begun when he was a schoolboy, continue to be applied in such diverse fields as cancer research and astrophysics. The project of deciphering and commenting on his rough notes continues at the University of Chicago and has yielded over a dozen volumes so far. Ashis Nandy who has analyzed the social and cultural context of Ramanujan's work, has drawn attention to the probable role of the cross-cultural encounter that led to such mathematical creativity.201It is probably no coincidence that Ramanujan's work was on the theory of numbers, in the tradition of Bhaskara II from the twelfth century. In any case, Ramanujan believed that his religious beliefs were integral to his mathematics, and his work can be interpreted as an Indian response to his first encounter with George Carr's mathematical text.202

Conclusion: Structure and Agency in the Institutionalization of Western Science in India

In the opening sections of this chapter, the complex social processes at work in the introduction and institutionalization of Western science and technology through education have been examined. It was argued that certain structural changes initiated by colonial rule, in combination with specific colonial policies led to the decline of indigenous educational institutions. In the changed social circumstances, the emergent *bhadralok* whose interests were tied to the

colonial administration, sought education in English and Western science in order to legitimize and consolidate their status in colonial society. Simultaneously, the utilitarian ideas of James Mill and Bentham, combined with the specific imperial imperative of training Indians to fill positions at the junior level in the colonial administration, led to a number of institutional changes in the sphere of education. Changes in official policy such as banning the use of Persian and the insistence on the use of English in the administration, Ram Mohun Roy's appeal to Amherst for education in Western science and English, and Macaulay's "Minute of 1835," delivered at a time when Bentinck's administration had already decided on a change in policy, led to the withdrawal of patronage for instruction in the indigenous sciences.

In the second section of the chapter, the impetus behind the gigantic public works undertaken under Dalhousie's administration and some of its consequences have been analyzed. The undertakings of the mid-nineteenth century, constituted the first large-scale state-sponsored enterprises in modern times, and the need for large numbers of trained engineers led to the establishment of engineering and technical schools in British India. These engineering schools were the very first in any part of the British Empire or England and were later replicated in England. However, although Western science and technology was institutionalized during the mid-nineteenth century, largely as a consequence of the public works, they were mainly geared toward increasing the agricultural productivity of the country. And the raison d'être for the introduction of the railways was the transportation of raw materials out of India to the factories of Lancashire and Manchester. Finally, the perception that Western science and technology could help in the production of more governable colonial subjects also informed much of colonial policy of the period.

After the era of the public works in the 1850s the next major phase in the institutionalization of Western science and technology was during Curzon's administration. Recurring famines led to the constitution of the Board of Scientific Advice, which, in liaison with the Royal Society, sought to guide the government in matters pertaining to science and technology. The institutional experiment with the Board of Scientific Advice inspired a number of similar organizations in England. By this time, a number of Indians, now trained in Western science, were demanding the creation of institutions where scientific research in areas other than agriculture could be undertaken. The creation of the Indian Association for the Cultivation of Science represented the response of Indian scientists to the existing situation. The association trained a number of Indian scientists in basic research, including C. V. Raman who was the first Asian scientist to win a Nobel Prize in 1930. At the same time, the newly constituted Indian National Congress was applying pressure on the colonial administration for the development of industries. The impetus for industrialization came on the eve of the First World War, when the possibility that the war might disrupt England's links with India, as well as the need to produce

munitions locally, led to the institution of the first Indian Industrial Commission. A number of reports were issued, but after the war was over, none of the recommendations of the commission were implemented.

By this time, the Indian scientists associated with the University College in Calcutta were playing a more active role in the development of scientific institutions in India. While some of them like P. C. Ray, believed that the application of scientific research for the development of heavy industries was not a suitable policy for India, the faction that thought otherwise was more dominant, and active in the emerging politics of the Indian National Congress. Led by Meghnad Saha, who was a leading scientist as well as an elected member of Parliament, this group of scientists was influential in setting the science and technology policy of preindependent as well as independent India. The Indian scientists did not respond uniformly to Western science and technology, but the group that was urging for heavy industrialization was dominant and its views resonated with the dominant factions of the Indian National Congress. These debates were also

influenced by the planning and heavy industrialization in the Soviet Union and by the TVA and atomic research in the United States. Although the policies finally adopted by India were not inevitable, they were conditioned by structural conditions constituted by colonial rule, the apparent success of modern science and technology in a number of societies at that time, and the active involvement of influential scientists in realizing their visions and worldviews for the future. To invoke Anthony Giddens' "structuration theory," 203the introduction of modern Western science and technology in colonial India involved a complex dialectic of structure and agency and cannot be attributed to purely structural factors or to the intentions and motivations of individual colonial administrators. Moreover the complex interplay of structure and agency also accounts for the active role that Indians, both scientists and nonscientists played in the institutionalization of Western science in colonial India. To view the introduction of modern Western science and technology as little more than a colonial imposition, as some writers have done, is to provide very mechanistic explanations for complex sociological issues.

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186. Ray, quoted in Visvanathan, 1985: 37.

187. Ray, quoted in Visvanathan, 1985: 38.

188. J. Nehru, quoted in Jagdish N. Sinha, 1991: 169. I rely on Sinha for the discussion on the role of the Congress party.

189. In this section I rely on Visvanathan, 1985.

190. Saha, cited in Visvanathan, 1985: 101.

191. Saha, quoted in Visvanathan, 1985: 108.

192. Saha, quoted in R. S. Anderson, 1975: 60.

193. The best account of the development of industrial research organizations in India can be found in Visvanathan, 1985.

195. G. H. Hardy, quoted in S. M. Fjellman, 1984: 102.

196. Hardy, cited in S. M. Fjellman, 1984: 102.

197. Cited in S. M. Fjellman, 1984: 102.

198. Hardy, quoted in Masters, 1992: 22.

199. Masters, 1992: 22.

200. *Ibid.*

201. A. Nandy, 1980.

202. Some studies on Ramanujan include: Hardy, 1959; S. R. Ranganathan, 1976; George E. Andrew, 1988; Robert Kanigel, 1991; A. Nandy, 1980.

203. Anthony Giddens, 1984. For a critique of Giddens' metatheory see Baber, 1991.

7
Conclusion: Science, Technology And Ecological Limits

God forbid that India should ever take to industrialization after the manner of the West. The economic imperialism of a tiny island kingdom (England) is today keeping the world in chains. If an entire nation of 300 million took to similar economic exploitation, it would strip the world bare like locusts.
M. K. Gandhi, 1928 1

The problem of distribution is not a whit less important than the problem of production; what do we gain if millions of our countrymen starve while a few fatten on unnatural grain? I need not be understood as saying all big scale industries should be smashed. The thing cannot be disposed away so airilyI could not even if I would. But surely you will agree with me that if the same result can be brought about by means much less harmful, surely that is preferable.
Prafulla Chandra Ray2

We do not for a moment believe that better and happier conditions of life can be created by discarding modern scientific techniques and reverting back to the spinning wheel, the loin cloth and the bullock cart. I believe and have proved that this insistence on primitive technology shows a very retrograde and antiscientific mentality, and persons who are wedded to this mentality would bring disaster to the country when they are in power. A new educational scheme should be devised by a world congress of the foremost thinkers like Bergson, Einstein, Russell, Smuts, Spengler and others, with the special objective of weeding out medieval passions from the minds of coming generations and for training them to a proper grip and sufficient appreciation of the beauty and power of science.
Meghnad Saha 3

Congress represents science, and science is the spirit of the age and the dominating factor of the modern world. Even more than the present, the future belongs to science and to those who make friends with science and seek its help for the advance of society.

Jawaharlal Nehru4

This study has examined the complex and conflicting social, economic, and political factors that were involved in the introduction and institutionalization of modern Western science and technology in colonial India. Colonial imperatives and the perceptions of British administrators played an influential role in this process. However, despite the overarching colonial structures, such imperatives and perceptions were not entirely homogenous, and at least in the initial stages of the consolidation of colonial rule, there were differences of opinion and competing viewpoints over specific policies vis-à-vis science and technology.

Within the larger context of colonialism, British naturalists and "scientists" played active roles in persuading colonial administrators of the potential economic and political significance of the introduction and application of modern Western science and technology. India represented a vast and unexplored territory for British naturalists and it held out the promise of potential careers in the emerging profession of science.5At a particular historical period, there developed a considerable degree of common ground between certain

colonial imperatives and the interests of British scientists. Despite initial resistance from the Court of Directors of the East India Company in London, the colonial administrators were eventually convinced of the importance of Western science and technology in the consolidation and legitimation of colonial power in India. The execution of the various statistical, trigonometrical, and topographical surveys in the early eighteenth century facilitated the exercise of colonial power and constituted a dynamic process whereby accurate scientific knowledge about hitherto unexplored territory facilitated the constitution of the modern nation state of India. After the era of the "great surveys," it was during the early decades of the nineteenth century that major changes in colonial policy, vis-à-vis science and education were introduced. Partly under the influence of the utilitarian views of James Mill, William Bentinck introduced a number of changes in education. Patronage for the instruction in the indigenous sciences was withdrawn and modern Western science and English were introduced in the curriculum in 1835. This change in previously existing policy received support from the emergent urban Bengali elite, the *bhadralok*, whose interests were dependent on the structures of colonial administration.

By the mid-nineteenth century, the colonial state was actively involved in sponsoring large-scale scientific and technological projects in British India. During Dalhousie's administration in the same period, British India constituted the site of one of the largest state-sponsored science and technology projects undertaken anywhere. These projects had significant consequences for the further development of science and technology as well as the evolution of Indian society.

By the time of Curzon's administration at the turn of the century, the perceived importance of science and technology as an integral component of colonial rule had been accepted by all of the colonial administrators. Scientific research and technological projects were increasingly deployed as technical solutions for social problems, such as continuing famines, which had emerged as a consequence of colonial rule. The dominant perception was that the intervention of scientific and technological forces could be substitutes for the structural changes that would be contrary to colonial interests. At the same time, the introduction of Western science and technology was supposed to engender and propagate a "modernizing" impulse that would facilitate the legitimation of colonial rule. Such perceptions were explicitly articulated in Curzon's claim that his administration was "trying to graft the science of the West on to an Eastern stem. [I]n proportion as we teach the masses, so we shall make their lot happier, and in proportion as they are happier, so they will become useful members of the body politic." 6Similar views were expressed by the engineer S. Goodfellow, who argued that "in prosecuting the study and in contemplating the structure of the universe they can scarcely fail of relieving themselves from a load of prejudices and superstition; they will thus gradually, in proportion as their knowledge is spread, become better men and better subjects, and less likely ever to be made the tools of any ambitious man or fanatic."7

Most of the large-scale "experiments" in scientific and technological institution building in British India were based on the assumption that precolonial India was almost devoid of any meaningful scientific and technological tradition. These views were shared by a number of scholars that included James Mill, Henry Maine, and Charles Trevelyan. Confronted

with ample evidence to indicate the existence of a precolonial scientific tradition, James Mill deployed considerable rhetorical skills to argue that what was present was of little consequence from a utilitarian perspective. Early British thinking on the issue and the perceived need to rectify the existing state of affairs were best articulated by Henry Maine who contended that "native thought and literature is elaborately inaccurate; it is supremely and deliberately careless of all precision in magnitude, number and time. [T]he Indian intellect stood in need, beyond and everything else, of stricter criteria of truth. [I]t required a treatment to harden and brace it, and scientific teaching was exactly the tonic which its infirmities called for." 8In the first few decades of the twentieth century, under pressure from a number of quarters for independence, Maine's views were revised by Alfred Chatterton, a member of the Indian Industrial Commission who argued that "when India can do her own engineering work and carry on her own industries, then, and only then will she be able to govern herself."9

However, as discussed in the second and third chapters of this study, precolonial ancient and medieval Indian society was not devoid of science and technology. At various periods in history, depending on the extent of patronage extended by the rulers, precolonial India exhibited varying degrees of development in science and technology. Without accepting the uncritical hyperbolic reconstructions of an idealized and largely imagined past, which are fueling the current round of religious and political strife in contemporary India, it is clear that the Indian contribution to modern science and technology has been considerable. Although an uninterrupted legacy of science and technology cannot be reconstructed, it is clear that even by 1765, which signals the onset of the first phase of British colonial rule, India had a virtual monopoly in some manufacturing sectors, such as textiles. It was only after the Industrial Revolution in Britain, an event that was partly precipitated by the conquest of Bengal, and the imposition of restrictive tariffs on Indian manufactured goods that the textile industries of India declined. In the years of colonial rule that followed, the social structure of India was fundamentally transformed, and the response of Indians to the introduction of Western science and technology has to be understood in the context of the structural and institutional transformations that followed.

The Indian response to the introduction of modern Western science and technology was not uniform and homogenous but represented a diverse range of views. However, in the context of the structural transformations ushered in by decades of colonial capitalism and by prevailing power relations, the dominant viewpoint was articulated by Ram Mohun Roy and much later by Sir Syed Ahmad Khan, both of whom accepted the narrative of modern science and

technology as the panacea for the resolution of social issues. While their response was not inevitable, it represented the views of the emergent and dominant elites and the middle classes, whose "life-chances" were linked to the structures of colonial administration. More than half a century later, in the context of the First World War, the Indian Industrial Commission provided the occasion, as well as the setting, for further discussions and debates about possible strategies for industrialization. Although the plans for developing heavy industries were shelved after the termination of the war, a new generation of Indian scientists, most of them trained in Britain, advocated the application of scientific research for the development of heavy industries.

However, P. C. Ray, one of the leading Indian scientists, who had earlier been the most ardent advocate of the development of heavy industries through laboratory-based research, changed his views drastically after participating in a series of famine and flood relief operations, and extended support for Gandhi's perspective on the issue. As Ray put it, "when Mahatmaji [Gandhi] in 1921 first made the *Charkha* [the spinning wheel] the symbol of the new movement, I myself, a staunch believer in mechanization, laughed at this relic of medievalism." Ray went on to argue against the indiscriminate development of heavy industries even while cautioning that he "need not be understood as saying all big industries should be smashed. The thing cannot be disposed away so airily." 10Ironically, Ray's students, organized under the *Science and Culture* group, headed by the physicist Meghnad Saha, were to emerge as his most outspoken critics. Saha combined the qualities of an outstanding scientist and statesman, and was intimately connected with the faction of the Indian National Congress opposed to Gandhi's program. As an elected member of parliament, Saha, together with his colleagues, played an active role in advocating the adoption of scientific and industrial policies that attempted to emulate the experience of Soviet Union and the Tennessee Valley Authority project as models. They accepted the dominant perception that increased investment in modern science and technology by itself could provide technically neutral solutions to the pressing social issues of independent India. Mahendara Lal Sircar, the founder of the Indian Association for the Cultivation of Science, articulated this worldview by quoting William Crooke, a British administrator who had argued that "it is the chemist who must come to the rescue of threatened communities. [I]t is through the laboratory that starvation may be eventually turned to plenty."11In the Indian National Congress, whose dominant faction believed that

"even more than the present, the future belongs to science and to those who make friends with science and seek its help for the advance of society,"12Saha and his colleagues found a powerful political ally for setting the science and technology policy for independent India.

Overall, within the wider context of colonial structures, both British and Indian scientists were active agents in the introduction of modern Western science and technology in India. In the process, new scientific knowledge and

institutions emerged, and, in general, the colonial encounter had significant consequences for the development of modern science and technology. To conceive of this process of institutional transfer of science and technology simply as an example of an "imposed intellectual tradition," vis-à-vis the "earlier organic knowledge of South Asia," 13is to simplify the complexities of the process. Clearly, although the specific response of a class of urban elite Indians to such Western science and technology was not inevitable, it has to be understood in the context of rapid institutional and structural transformations induced as a consequence of colonial rule. To represent the process as the displacement of an indigenous system of science by an alien one is to ignore the complex process of negotiation, contestation, cooptation and resistance at work. In the end however, as David Arnold has argued in a recent study of medicine in colonial India, the emerging Indian elite was to take up Western science as "part of their own hegemonic project."14

In recent years, a number of Indian scholars have engaged in incisive critiques of "modern Western science" and its complicity with colonial rule.15While some of these scholars have no doubt facilitated critical reflection on some of the negative consequences of the practice of modern science and technology, others have considerably oversimplified the issues. Such critiques run the risk of uncritically idealizing and reifying concepts and ideas like "India's traditional cultures and ways of life," its "traditional systems of knowledge struggling against the hegemony of modern science," and the "purity of traditional systems of knowledge."16Such characterizations reinforce a simplistic tradition-modernity dichotomy and imply the existence of hermetically sealed cultures and societies frozen in time suddenly exposed to external and alien influences. As this study has indicated, neither ancient nor medieval India was ever isolated from other cultures and society, and, in fact, a number of Indian scientific ideas, concepts, and techniques actively contributed to the development of modern "Western" science and technology.

Other Indian critics have attempted to link "reductionist science" and the "internally determined structure and content of the system of scientific knowledge" with almost every conceivable social problem in India, including "epistemological violence."17Thus the Indian critic Claude Alvares has contended that "analysis of the connection between science and violence is itself part of an analytical structure that could be used to explain other forms of violence."18Colonial rule, conceived of as a socially disembodied process with a logic of its own, is identified by Alvares as the agency responsible for ensuring that "colonial science has survived colonialism's formal departure from the third world in the form of the Trojan Horse."19All these views rely on the implicit assumption that the development of science and technology is driven by an unfolding logic, unaffected by society or social relations.

While there is no doubt that the advent and consolidation of colonial rule fundamentally transformed precolonial science and technology, the process

was far more complex and did not involve a simple imposition of a particular "reductionist" scientific worldview from the top. Any critique that ignores the embeddedness of modern science and technology in the wider social structures risks indulging in voluntarism which assumes that a "humane," "non-reductionist," "holistic," or "non-Western" model of science can be conceptualized and applied to societies at will. Overall it is doubtful whether, in this age of relative globalization, concepts such as "Western" and "non-Western" science constitute anything more than relative categories. This is not to argue that science and technology are socially neutral terms that can be applied to any society. Some of the negative consequences of the much vaunted "green revolution" in India amply testify against such an assumption. 20But there are alternative ways of understanding and explaining the lack of suitability of specific technologies in quite different contexts without resorting to a cultural reductionism that would radically distinguish between "Western" or "Eastern" technology. Such cultural reductionism may be morally self-satisfying, but the premises on which such assumptions are

based do not stand up to historical scrutiny. Moreover such culturalist endeavors as the search for Eastern, Islamic, or Hindu sciences seriously limit critical reflection on some of the negative consequences of specific technologies on real people in the real world, while conjuring fantasies of specific science and technologies for apparently hermetically sealed cultures and societies.21

While this study has been critical of some of the consequences of colonial rule, a word of caution is necessary against the tendency all too common among contemporary academics of invoking "colonialism" as the sole explanatory device in accounting for almost every aspect of society and politics in contemporary India. The legacy of colonial rule is now being used to explain the existence of the caste system, caste conflict, the ongoing communal (sectarian, ethnic) violence, the Punjab problem, *sati*, female infanticide, etc. Thus Ashis Nandy, one of the strongest critics of an undifferentiated and reified concept of "rationality," "modernity," and the "modern scientific worldview," commenting on a much publicized case of *sati* in 1987, explained it as a consequence of the "pathology of colonialism," and argued that the burning alive of Roop Kanwar represented "the desperate attempt to retain through *sati* something of the religious world view in an increasingly desacralized secular world." Blaming "modern political economy" and the modern scientific worldview, Nandy argued that the death of Roop Kanwar on the funeral pyre of her husband constituted an event reaffirming "respect for self-sacrifice in a culture in which there is no scope or legitimacy for self-sacrifice."22The issue of why exactly women and not men were selected for this mode of affirming the legitimacy for self-sacrifice was not discussed. Similarly, Patrick Harrigan expressed disappointment at the response of "irate feminists," some politicians, and the courts for attempting to prevent a recurrence of the event. Harrigan valorized "traditional modes of thought" against

the "modern mentality" that was allegedly introduced during colonial rule, and described the event as "reminiscent of Rajasthan's days of glory." 23As Aijaz Ahmad has recently pointed out, in contemporary India, "colonialism is now held responsible not only for its own cruelties but, conveniently enough, for ours too."24In a similar vein, Akeel Bilgrami has drawn attention to some intellectuals' "neurotic obsession with the Western and colonial determination of their present condition," pointing out quite acutely that "it will prove a final victory for imperialism that after all the other humiliations it has visited it has lingered in our psyches in the form of genuine self-understanding to make self-criticism and free, unreactive agency impossible."25Although the guiding metatheoretical assumption of this study has been that the present cannot be adequately comprehended without an understanding of the past, the limits to the powers of the "hidden hand" of history should be kept in perspective.

The critique of modern science and technology, especially in view of the fact that it is directly implicated in the ensuing ecological crisis, is a fruitful first step. However, at times, such critiques tend to oversimplify the issues by invoking specific attitudes like "domination of nature," "mechanistic worldview," the "Judeo-Christian tradition," and a "Eurocentric worldview" as being exclusively responsible for the trajectory modern science and technology has taken.26While such critiques may be valid to a point, they ignore the social conditions that facilitated the dominance of such views and the fact that even in western Europe, there were a multiplicity of discourses about nature and science. There were a number of "other minds" of Europe like Goethe, Paracelsus, Giordano Bruno, etc. who sharply criticized the emergent mechanical scientific worldview, albeit for very different reasons.27In view of the prevalence of a multiplicity of discourses on science and technology, the key sociological task is a sociohistorical examination of the "elective affinities" between particular social structures and the domination of specific worldviews on nature, science and technology. The recent culturalist critiques of "Western" science and its alleged alien nature vis-à-vis "Eastern" societies ironically reproduce the very Eurocentric discourses they claim to challenge and dismantle.28Such critics assume that modern science is a uniquely "Western" institution that has no antecedents or precursors in other societies and cultures. That such assumptions should continue to inform thinking on this issue is surprising, especially after the monumental work of Joseph Needham. Although this study has not directly tackled the "Needham question,"29the relatively independent traditions of science and technology in ancient and medieval India, combined with complex transcultural and transsocietal interdependencies of scientific ideas and institutions during the precolonial period make it rather difficult to maintain the purity of "Western" science. The strikingly identical claims are advanced simultaneously by the defenders of the "West" and its radical Eurocentric critics is itself worthy of further sociological analysis. In the current heady fascination with postmodernism, now reincarnated as postcolonialism after the requisite dollop

of third-worldism, the larger structural factors, especially the emergence and consolidation of global capitalism, have been explicitly ignored. 30

In the case of India, Jawaharlal Nehru has been the object of severe criticisms for importing and imposing a "Western" worldview of science and technology in postcolonial India. However, such critiques unfairly gloss over the predicament of Nehru, assigning the responsibility to a single individual, and rarely examine the complex constellation of historical and sociostructural conditions that contributed to the policy of massive investments in "big science" and technology for heavy industrialization in independent India. It is only now that some of the problems of such policies are becoming apparent since "third world capitalism," at least in the case of India, represents in the words of Guha, "a gross caricature of European capitalism, reproducing and intensifying its worst features without holding out the promise of a better tomorrow."31One need not be a Gandhian to realize the significance of his warning in 1928: "God forbid that Indian should ever take to industrialization after the manner of the West. The economic imperialism of a tiny island [England] is today keeping the world in chains. If an entire nation of 300 million took to similar economic exploitation, it would strip the world bare like locusts."32Toward the end of his life, Marx, in his correspondence on the institution of the *mir* in Russia, also expressed strong misgivings about his earlier conception of the inherently progressive nature of capitalism.33Ramachandra Guha has recently argued that the development of capitalism and industrialization in Europe emerged from a unique set of circumstances, and "if the transition to both industrialism and capitalism must necessarily remain incomplete in most of the Third World, the primary reason is *ecological*."34However, current policies on science, technology, and the economy in India do not indicate any acknowledgment of either ecological limits or the social consequences of such policies.

Notes

1. M. K. Gandhi, 1966, quoted in Guha, 1990b: 43147.

2. P. C. Ray, quoted in S. Visvanathan, 1985: 38.

3. Meghnad Saha, quoted in Visvanathan, 1985:101108.

4. Jawaharlal Nehru, quoted in Deepak Kumar, 1991: 169.

5. See Ray Desmond, 1992, for a recent study of the impact of the European discovery of Indian flora on the development of modern botany.

6. India Office Library and Records. *Curzon Papers*. Mss. Eur. F111/559: xi; xvi.

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7. S. Goodfellow, quoted in R. Dionne and R. Macleod, 1979: 60.

8. Henry Maine, quoted in R. Strachey, 1911: 297.

9. Alfred Chatterton, 1912: 359.

10. Ray, quoted in Visvanathan, 1985: 3738.

11. Mahendar Lal Sircar, quoted in Visvanathan, 1985: 25.

12. Nehru, quoted in J. Sharma, 1991: 169.

13. S. Goonatilake, 1984: 41.

14. David Arnold, 1993.

15. See A. Nandy, 1988, for a comprehensive and representative collection of such critiques.

16. Nandy, 1988: 7, 11, 12.

17. Vandana Shiva, 1988: 255.

18. Claude Alvares, 1988: 71.

19. *Ibid.*, 92.

20. See F. Frankel, 1971, and S. Yearley, 1988, for accounts of the consequences of the Green Revolution in India.

21. For critiques of such culturological explanations see V. Kaiwar, 1994; P. Hoodbhoy, 1991; M. Nanda, 1991; S. Mitter, 1994.

22. Nandy, 1987; for incisive critiques, see K. Sangari, 1988; Baber, 1996.

23. P. Harrigan, 1987.

24. A. Ahmad, 1992: 19697.

25. Akeel Bilgrami, 1994: 1763.

26. Proponents of this argument include Lynn White Jr., 1973; B. G. Norton, 1987; J. Passmore, 1974. For critical discussions of these issues see R. Grundmann, 1991; A. Ross, 1991; Z. Baber, 1994; M. Lewis, 1992.

27. The diversity of views on nature and technology in western Europe has been examined in the following studies: J. P. S. Uberoi, 1984; F. A. Yates, 1964; A. Debus, 1965, 1978; K. Thomas, 1983; For a recent discussion of the controversy between Goethe and Newton on the theory of colors, please see J. W. Myles, 1994; D. Bjelic and M. Lynch, 1994.

28. Vandana Shiva, 1988b; Nandy, 1988, and Alvares, 1988, exemplify this genre of culturalist critique. For a sociologically sensitive critique of

Western concepts and theories that encourages critical engagement rather than utopian dismissal of social science as it has been practiced so far, see Syed Farid Alatas, 1993a. Refreshingly, unlike the above mentioned scholars, Alatas (1993b) demonstrates how his ideas on the indigenization of academic discourse can be applied to specific social settings.

29. For a recent attempt to tackle the "Needham question," see Toby E. Huff, 1993. For a critique of the critque of Needham, see Matthew Guttman, 1992.

30. For recent critical discussions of the culturalist assumptions underlying much postcolonialist discourse, see Arif Dirklik, 1994, and Aijaz Ahmad, 1992 and 1995.

31. Ramachandra Guha, 1990: 195.

32. M. K. Gandhi, 1966: 26, 28, 3132.

33. T. Shanin, 1983.

34. Guha, 1990: 195.

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